Universidade Federal
do Rio de Janeiro
Escola Politécnica

DESIGN OF THE SUPPLY CHAIN FOR A NEW FIELD HOCKEY COMPANY IN SOUTH AMERICA

Guillem Ribó Torres

Projeto de Graduação apresentado ao Curso de Engenharia de Produção da Escola Politécnica, Universidade Federal do Rio de Janeiro, como parte dos requisitos necessários à obtenção do título de Engenheiro.

Orientador: Lino Guimarães Marujo

Rio de Janeiro

Julho de 2019

DESIGN OF THE SUPPLY CHAIN FOR A NEW FIELD HOCKEY COMPANY IN SOUTH AMERICA

Guillem Ribó Torres

PROJETO DE GRADUAÇÃO SUBMETIDO AO CORPO DOCENTE DO CURSO DE ENGENHARIA DE PRODUÇÃO DA ESCOLA POLITÉCNICA DA UNIVERSIDADE FEDERAL DO RIO DE JANEIRO COMO PARTE DOS REQUISITOS NECESSÁRIOS PARA A OBTENÇÃO DO GRAU DE ENGENHEIRO DE PRODUÇÃO

Autor:

____

Guillem Ribó Torres

Orientador:

____

Lino Guimarães Marujo, D. Sc.

Examinador:

____

Prof. Roberto Ivo da Rocha Lima Filho, D. Sc.

Examinador:

____

Prof. Luan Santos, D. Sc.

Rio de Janeiro – RJ, Brasil

Julho de 2019

Declaração de Autoria e de Direitos

Eu, *Guillem Ribó Torres,* Passaporte *PAH620221*, autor da monografia *Design of the supply chain for a new field hockey company in South America,* subscrevo para os devidos fins, as seguintes informações:

1. O autor declara que o trabalho apresentado na disciplina de Projeto de Graduação da Escola Politécnica da UFRJ é de sua autoria, sendo original em forma e conteúdo.
2. Excetuam-se do item 1. eventuais transcrições de texto, figuras, tabelas, conceitos e ideias, que identifiquem claramente a fonte original, explicitando as autorizações obtidas dos respectivos proprietários, quando necessárias.
3. O autor permite que a UFRJ, por um prazo indeterminado, efetue em qualquer mídia de divulgação, a publicação do trabalho acadêmico em sua totalidade, ou em parte. Essa autorização não envolve ônus de qualquer natureza à UFRJ, ou aos seus representantes.
4. O autor pode, excepcionalmente, encaminhar à Comissão de Projeto de Graduação, a não divulgação do material, por um prazo máximo de 01 (um) ano, improrrogável, a contar da data de defesa, desde que o pedido seja justificado, e solicitado antecipadamente, por escrito, à Congregação da Escola Politécnica.
5. O autor declara, ainda, ter a capacidade jurídica para a prática do presente ato, assim como ter conhecimento do teor da presente Declaração, estando ciente das sanções e punições legais, no que tange a cópia parcial, ou total, de obra intelectual, o que se configura como violação do direito autoral previsto no Código Penal Brasileiro no art.184 e art.299, bem como na Lei 9.610.
6. O autor é o único responsável pelo conteúdo apresentado nos trabalhos acadêmicos publicados, não cabendo à UFRJ, aos seus representantes, ou ao(s) orientador(es), qualquer responsabilização/ indenização nesse sentido.
7. Por ser verdade, firmo a presente declaração.

____

Guillem Ribó Torres

UNIVERSIDADE FEDERAL DO RIO DE JANEIRO
Escola Politécnica – Departamento de Produção
Centro de Tecnologia, bloco F, sala F-100, Cidade Universitária
Rio de Janeiro – RJ CEP 21949-900

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisor Lino Marujo Guimarães for being there, helping me when it was necessary and giving useful advices to achieve a better master thesis. Furthermore, I would like to thank Guilherme from Canário Hóquei, for sharing the information and being the perfect link with the only Brazilian hockey company selling hockey material. To all the hockey federations that helped me with a lot of the data that was necessary, thank you very much, without you this project would be impossible. Thanks to UFRJ for accepting me in this amazing experience, working with one of the best universities in South America in one of the most beautiful cities worldwide. Finally, I would like to thank my loved ones, who have supported me throughout entire process, my family and my best friends. I will always remember the love you gave me.

ABSTRACT

Field hockey is a growing sport, even as important brands as Adidas have entered the market in recent years investing a large amount of money. The surprising thing about this sport is the process of making the hockey sticks. Practically all brands, except very few, produce in Asia, but curiously produce in the same factories. All the sticks that are on the market start from the same molds and the same materials.

Why there are very few companies that choose to manufacture in their own country and develop their own molds and sticks? Basically, because almost all the brands are too lazy to innovate about a product that works correctly. Why this product is not manufactured in South America with the large number of players there are? Is it possible to create a factory and distribution center in this huge part of the American continent? Recall that Argentina is the current Olympic champion or that countries like Chile and Brazil do not stop growing.

In short, this project is about creating a field hockey company in South America. Attending to important factors such as the creation of the supply chain and the big questions that this entails.

Keywords: Supply Chain, Field Hockey, Logistics, South America

ACRONYMS

UFRJ – Universidade Federal do Rio de Janeiro

FIH – International Federation of Hockey

UPC – Universitat Politècnica de Catalunya

MAD – Mean Absolute Deviation

MSE – Mean Squared Error

SABI – Iberian Balance Sheet Analysis System

Table of contents

List of figures

List of tables

1. Preface

1.1. Origin of the project

Since I arrived in Brazil, I knew that I wanted to work with the supply chain and logistics, but I did not have the product I wanted to do very clear. When I started playing hockey here with Carioca Hóquei Club, I saw that many players were using the same stick brand. I asked where it was possible to buy a stick and they told me that in Brazil there is only one hockey brand, everything else matters through a contact with Europe. This contact turned out to be the father of one of my teammates. How can a country with more than 200 million inhabitants and more than 7,000 players have only one physical store to buy? Because material does not arrive on the internet either. So, I researched and saw that 99% of the sticks are produced in the same city (Sialkot, Pakistan) and I think that with the number of players in South America, this project covers a large market niche.

1.2. Motivation

During the last year of the master's degree, I have carried out works on supply chain on a small scale and to be able to carry out such an ambitious project in South America it seems to me of the most difficult and entertaining challenges I have done in the university. In addition, when playing hockey both in Spain and now here in Brazil, it makes it even more interesting because I know South American hockey in person. In short, South America is a very interesting region with great potential, and I also work on one of my greatest passions, field hockey.

2. Introduction

2.1. Issue of the project

Hockey in South America is booming. Argentina is already one of the best national teams worldwide and some countries like Chile and Brazil improve year after year. With such many players and a continent with so many business opportunities, how would be to create a field hockey factory in South America? Nowadays, the majority of the sticks are produced in due to its great knowledge of the sport and its cheap labor. The question is: What if this niche of market really deserves to be studied? South America and the world of field hockey grow together.

2.2. Project goals

The objective of this project is to design the most important factors of the supply chain for a new field hockey company in South America. The specific objectives implied by this supply chain are:

- Identify the most important countries.
- Define very well what product is going to be sold. This implies knowing all the variants of sticks.
- Create a forecast model
- Define a production and capacity plan
- Find the best location for the factory and the warehouse
- Try to understand how the reverse logistics of this product would be
- Analyze the environmental impact

Apart from all these goals, it is also important to work in a new continent, deal with some hockey companies and understand how the hockey world works here.

2.3. Scope of the project

The supply of this project is limited to analyzing some of the most important factors of the supply chain. In addition, forecasts are planned for future years, but in the short term there is no intention to build any company. Talking with many hockey companies, some of them have been interested and think it is a good market niche, but today it seems to be a huge challenge.

2.4. Planning

This section presents a first planning of the months that the project lasts, which begins at the beginning of March and is presented in the middle of July. In short, the table that is attached below is a tool that is created at the beginning of the project in order to make a small follow-up and not lose the thread of the work, it is only used at the orientative level.

Month of the year	Activities list
March	- Exposition of the problem - Planning - Study the state of art and the viability of the project
April	- Sales forecast
May	- Capacity - Location
June	- Distribution - Reverse Logistics
July	- Environmental impact - Present the project

Table 1: Idea of the initial planning of the project as an orientation
Source: Own elaboration

3. Field Hockey

3.1. Introduction

Field hockey is a team game of the hockey family. The earliest origins of the game date back to the Middle Ages in India. The game can be played on grass, water turf, artificial turf or synthetic field as well as an indoor board surface. Each team plays with eleven players, including the goalie. Players use sticks made from wood, carbon fiber, fiber glass or a combination of carbon fiber and fiber glass in different quantities (with the higher carbon fiber stick being more expensive and less likely to break) to hit a round, hard, plastic ball. The length of the stick is based on the player's individual height. Only one face of the stick is allowed to be used. Goalies often have a different kind of stick; however, they can also use an ordinary field hockey stick. The specific goal-keeping sticks have another curve at the end of the stick, this is to give them more surface area to save the ball. The uniform consists of shin guards, shoes, shorts, a mouth guard and a jersey. Today, the game is played globally, mainly in parts of Western Europe, South Asia, Southern Africa, Australia, New Zealand, South America (specially Argentina, Chile and Brazil) and parts of the United States (primarily New England and the Mid-Atlantic states). Known simply as "hockey" in many territories, the term "field hockey" is used primarily in Canada and the United States where ice hockey is more popular. **[1]**

3.2. Field hockey stick

Much of the information in this chapter has been drawn from a hockey guide on the SPORTS Unlimited website **[2]**. There are parts with other sources (also indicated) and some parts of own elaboration.

Since just before the 19th century, modern field hockey had evolved in England and today, it has developed into a universal sport. A field hockey stick is your most valuable asset on the field. It not only compliments the player skills, but it also contributes to the performance by allowing the player to execute outstandingly come game time. The field hockey stick has different parts with different names that must be shown in order to understand the following parts of this project.

Figure 1: Parts of a field hockey stick
Source: SPORTS Unlimited website **[2]**

There are many factors to analyze when a player is trying to buy a new stick. In order to understand better all the factors, the player should consider the following features before making a purchase:

- Level of Play
- Position
- Size
- Toe Design
- Bow
- Composition
- Weight

– **Level of Play**: the most expensive stick is not necessarily the best field hockey stick for a new player. That's because, typically, the more expensive hockey sticks have a high carbon content, making them pretty powerful, but also really stiff. This stiffness and power make it a lot harder to stop the ball, control it, and maneuver it on the field, making that expensive stick pretty difficult to use for newer players.

– **Position**: Although, these days, most field hockey sticks are fairly light and easy to maneuverer, there are still variations in weight that make a stick more appropriate for a player or position. Typically, manufacturers provide approximate weights for the 35" or 36" versions of their sticks, but to find the weight of a size stick, simply add or subtract about 10 grams for every inch. Once a player has the weight of the stick, assess which position the stick is designed for:

  - 19 - 20 ounces (approx. 540 - 565 grams) - Designed for forwards, a lightweight stick doesn't interfere with, or hold back rapid stick work.

- 21 ounces (approx. 595 grams) - Designed for midfielders, a mid-weight stick benefits both defensive and offensive maneuvers.
- 22 - 24 ounces (approx. 620 - 680 grams) - Designed for backs, the heavier sticks put serious power and distance behind your shots, making them great for clearing the ball.

– **Size**: Field hockey sticks come in a wide range of lengths, to fit any size or age player on the field. Ranging from about 28" to 38" long, field hockey stick length can drastically affect the game and the comfort on the field. For instance, a stick that is too long will be clunky and difficult to maneuverer and may limit the agility on the field. On the other hand, a stick that is too short may not let the player get enough power behind his shots and passes, limiting the range on the field.
There are two standard methods for finding the appropriate stick length for your body; the U.S. Method, and the Dutch Method, found below:

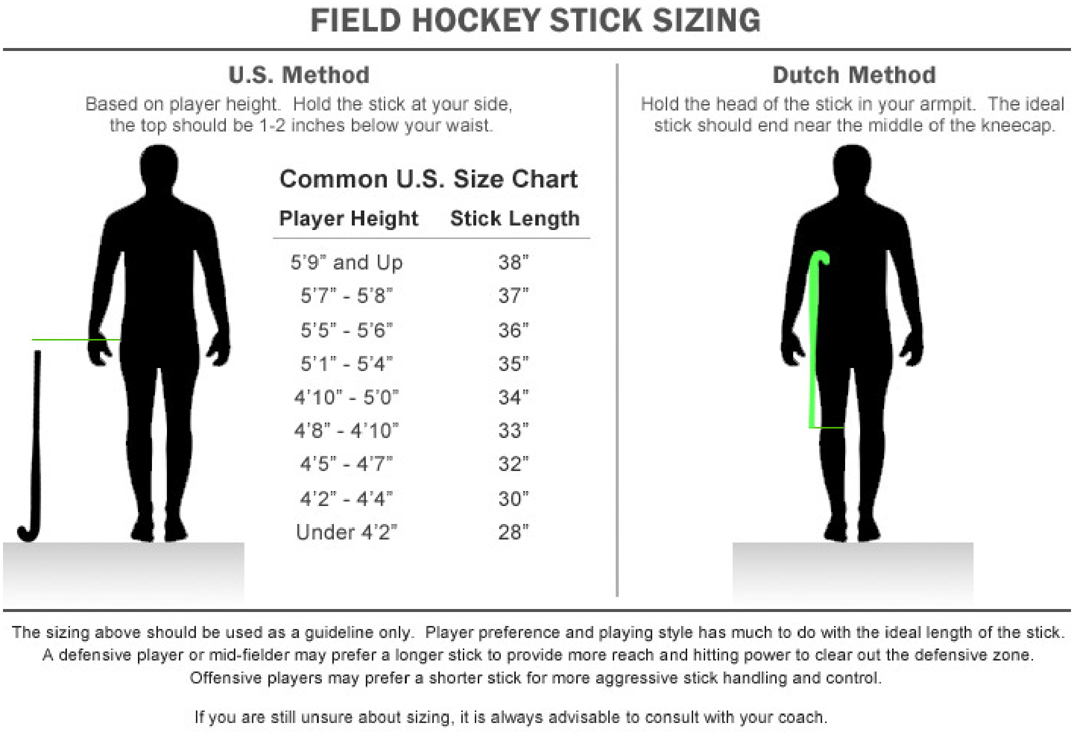


Figure 2: Correct way to choose the best stick size
Source: SPORTS Unlimited website **[2]**

– **Toe Design**: A stick's toe is curved and designed to complement that way a player strikes the ball and handles the stick. Smaller toes provide maximum manoeuvrability and agility, while limiting striking surface and power, while larger toes provide plenty of striking and receiving area for the ball, while reducing the stick's overall manoeuvrability. Typically, field hockey stick toes come in four shapes:

- Shorti - A very common toe length, great for quickly turning the stick over the ball. Generally used by offensive players for its balance, manoeuvrability, and control.
- Midi - By far the most widely used toe shape for beginners and (as the name implies) midfielders. Slightly longer than Shorti toes, Midi toes allow for a larger hitting surface without reducing agility, making flicking, receiving, and reverse play easier and more comfortable, especially for newer players.
- Maxi - The largest standard toe, Maxi toes are preferred by defensive players for their wide striking and receiving surface, along with solid power.
- Hook - A J-shaped toe, the Hook is a two-piece head that allows for extra surface area, designed to increase ball control for better drag-flicks and reverse stick play.

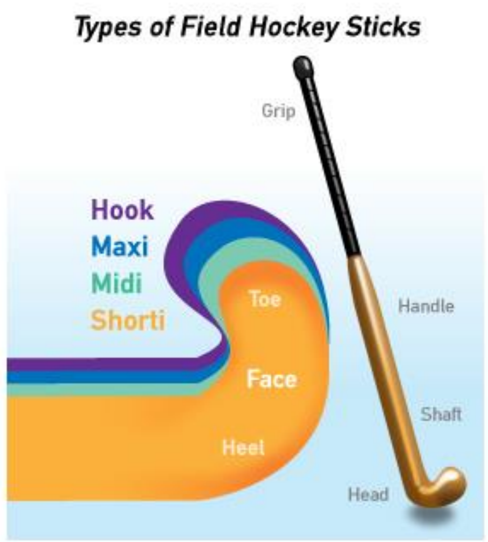


Figure 3: Types of field hockey hooks
Source: SPORTS Unlimited website **[2]**

– **Bow**: Almost every advanced composite stick you'll see has a bow in the shaft, meaning the stick bends slightly from the handle to the toe. Most sticks feature a

20mm bow, but others can range up to 25mm. The bow can also shift from stick to stick, altering the when the center of the stick falls, and changing the way it plays. For instance, a standard bow benefits every area of the game equally, while a more dramatic bow creates a more dramatic head angle, to assist in dynamic controls and lifts. Bow choice should depend on preference, age, and skill level. Understand the three types of bows to get a better idea of which stick is right for you:

- Standard Bow: Typically measuring 20 - 25mm, with a regular bow, the highest point of the bend falls in the middle section of the stick. This makes for well-rounded performance, assisting in every aspect of the game from ball control to advanced maneuvers.

Figure 4: Dimensions of a Standard Bow stick
Source: OSAKA HOCKEY website **[3]**

- Mid Bow: With a control, or mega bow, the center of the bend moves closer to the to toe, to provide extra power when lifting the ball and drag flicking. Meant for more advanced players, this bow allows for dynamic control and competitive level maneuvers

Figure 5: Dimensions of a Mid Bow stick
Source: OSAKA HOCKEY website **[3]**

- Low Bow: Measuring 24mm, the low bow, or late bow, places the bend at the furthest end of the stick, right before the head. The late bow is meant for elite level players, and delivers extra assistance when controlling the ball, lifting the ball, performing aerials, and drag flicking.

Figure 6: Dimensions of a Low Bow stick
Source: OSAKA HOCKEY website **[3]**

– **Composition**: Field hockey sticks were once all made out of wood, but those days are no longer. While you can still find solid wood sticks out there, most modern and higher-level sticks are composite, or made of a combination of materials. Varying levels of composites alter the performance, weight, power, and stiffness of a stick, as well as its price. So to make sure you're getting the right stick for your skill level and needs, it's important to know what each material offers, and what it is designed for:
    - **Carbon**: Designed for stiffness and rigidity, greater carbon content in a stick gives it harder hits and more power. Carbon content can run as high as 90% of a stick's make-up, although even a 50% carbon stick is still going to give you elite-level power. Carbon-heavy sticks are inherently less-forgiving than other materials and require greater skill to maneuver and wield. They also tend to be a little heavier than other sticks. Sticks with more carbon content are recommended for advanced and elite-level players.
    - **Fiberglass**: Found in almost every composite field hockey stick on the market, in some level, fiberglass adds durability, power, and feel to a stick. Similar in nature to carbon, but more economical, fiberglass delivers the feel of a high-end, high-performance stick without the high price tag. Fiberglass sticks also tend to be lighter, and less rigid than carbon-heavy sticks, making them more forgiving and better designed for young, new, or developing players.
    - **Aramid**: Meant to dampen and absorb vibrations sent through the stick when striking and receiving balls, aramid is a great balancing material found in many field hockey sticks. **Kevlar** can be also used with the same function

of Aramid. Aramid and Kevlar are used to create the composite with fiberglass. The main material in a composite is the fiberglass, but the aramid/Kevlar are necessary to use fiberglass during the manufacturing process.

- **Wood**: Modern wooden sticks still exist, although most are wrapped in fiberglass to add strength and power. Known for their natural feel and solid control, as well as their lower price tag, modern wooden sticks are great for young and developing players.

3.3. Manufacturing process

3.3.1. Where and how is the stick made?

Nowadays there are very few companies today that make the sticks on their own. In fact, it is known that Crown Hockey is the only company that makes sticks on its own. All other hockey brands, which are a lot, manufacture their products in Asia. Although there are some factories in China or India, 90% of the sticks produced worldwide come from the same part: Sialkot, in Pakistan.

Figure 7: Location of Sialkot on the map
Source: World Atlas **[4]**

Once known where the main production of hockey sticks is located around the world, it is analyzed the process of manufacturing the sticks. Much of the information used below is based on 4 YouTube videos that show the functioning of these factories in Sialkot, Pakistan. **[5] [6] [7] [8]**

<u>Manufacturing process:</u>

1) **3D Modelling:** the first thing that must be done before any manufacturing process is the 3D modelling part. The complexity of a stick is not very big, but it is important to indicate the dimensions required.

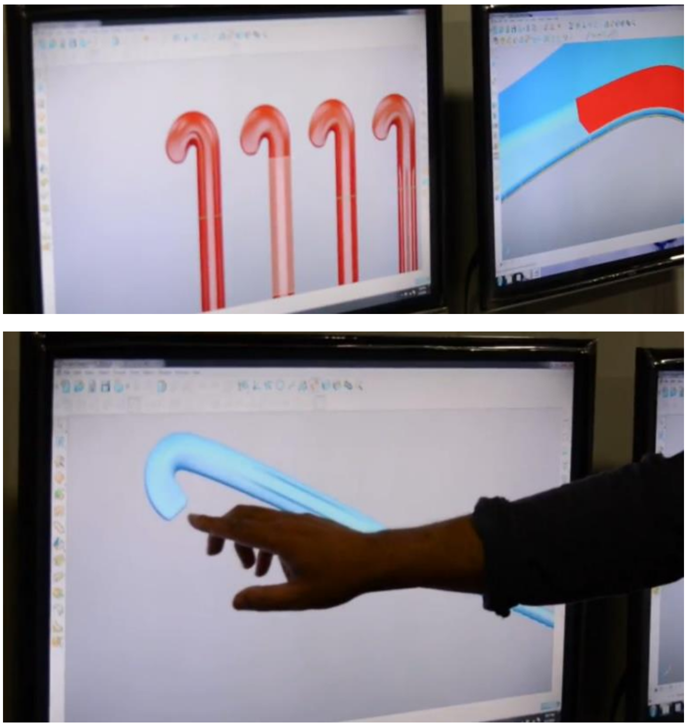


Figure 8: Process of 3D Modelling a field hockey stick
Source: Decathlon Hockey, YouTube **[5]**

2) **Carbon layer making & Fiberglass:** with these giant rolls the carbon fiber sheets (dark gray) and fiberglass (whiter color) are made. Once the sheet is made on the roll, it is first cut into smaller sheets and then into strips to better shape the stick.

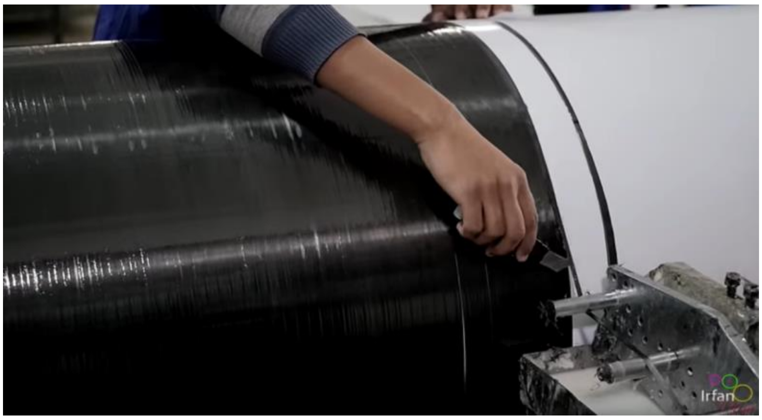


Figure 9: Carbon layer process making on the roll
Source: Irfan Saghir Mirza, YouTube **[7]**

3) **Hockey strip making:** once the strips of carbon fiber or fiberglass are made, they come together forming the shape of what will be the hockey stick. On the following figure there is a worker doing a fiberglass strip (white color, the image above) and another one doing the carbon fiber one (dark color, image below).

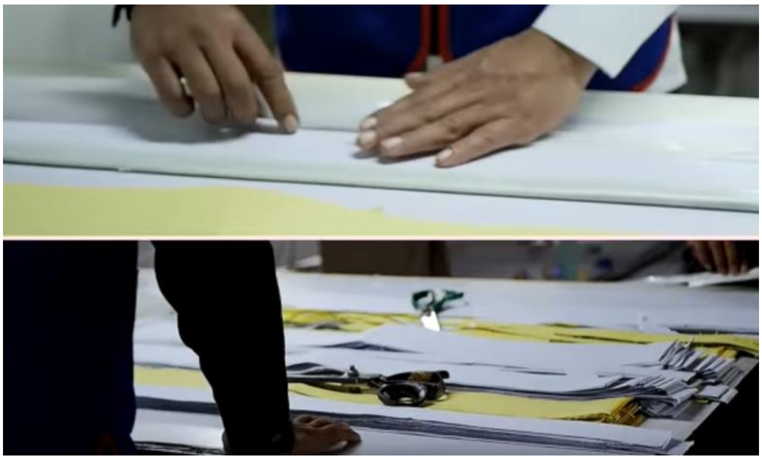


Figure 10: Hockey strip making
Source: Irfan Saghir Mirza, YouTube **[7]**

4) **Calibrate the curvature and weigh**: it must be seen that the shape of the stick before entering the mold is correct and that the weight is within acceptable ranges.

Figure 11: Measuring the weight of the stick
Source: Irfan Saghir Mirza, YouTube **[7]**

5) **Mold preparation.**

Figure 12: mold preparation before introducing the materials
Source: Decathlon Hockey, YouTube **[5]**

6) **Make the top of the stick with a mold:** the picture below shows the shape of the cap that goes on the top of the stick:

Figure 13: Cap of the top part of the stick
Source: Decathlon Hockey, YouTube **[5]**

7) **Giving to the sticks the final shape:** basically, the most important thing here is to create the shape of the hook in order to introduce the stick correctly into the mold.

Figure 14: Stick's hook fits with the mold
Source: Irfan Saghir Mirza, YouTube **[7]**

8) **Cooking (20 minutes):** it is very important to cook the stick before blowing the air, if the material is not hot it would not get the shape of the mold correctly.
9) **Blowing air into the stick:** the air is injected into the mold through the wires that appear on the right of the image shown below.

Figure 15: Air blow into the mold
Source: Decathlon Hockey, YouTube **[5]**

10) **Remove the stick from the mold:** the stick comes out of the mold with imperfections that have to be corrected before proceeding to paint.

Figure 16: Removing the stick out of the mold
Source: Decathlon Hockey, YouTube **[5]**

11) **Paint making, spray painting and water decal:** first it is necessary to prepare the paint, then spray it and finally add the final water decal to the stick.

12) **Finishing:** giving the stick the last details to get the final look.

Figure 17: Finishing process
Source: Irfan Saghir Mirza, YouTube **[7]**

13) **Drying area:** the paint must be dried into a room for a while.

Figure 18: Drying area
Source: Decathlon Hockey, YouTube **[5]**

14) **Sticks final touch:** the most important things to finish the stick are the gripping (on the left) and putting the cap on the bottom of the stick (right picture).

Figure 19: Sticks final touch
Source: Decathlon Hockey, YouTube **[5]**

15) **Size and weight measurement.**

16) **Final quality check.**

17) **Ring test:** the ring must go from the top to the hook of the stick with no problem.

Figure 20: Ring test
Source: Decathlon Hockey, YouTube **[5]**

18) **Packaging:** the stick is introduced into a plastic bag.

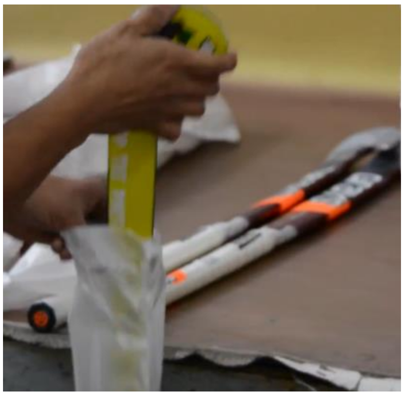


Figure 21: Packaging of the stick
Source: Decathlon Hockey, YouTube **[5]**

3.3.2. Market niche in South America

In South America there are many hockey federations and some countries are important worldwide. The most important in a very prominent way is Argentina. In the men's category it is the current Olympic champion. On the other hand, Chile is a very good country also in hockey and Brazil is improving year after year. The number of existing players in South America is very large, especially in Argentina, and they all buy through a few retailers. There are no brands manufactured in South America and in countries like Brazil on the internet there is nothing at the national market.

In the top 50 national teams there are some of the South American teams. On the following table there are the national teams that appear on the top 50 by FIH (International Hockey Federation) on male and female rankings:

	MEN’S WORLD RANKIGNS	WOMEN’S WORLD RANKING
Argentina	4	3
Chile	28	15
Brazil	29	Out of TOP 50
Uruguay	43	25
Trinidad and Tobago	37	Out of TOP 50
Peru	Out of TOP 50	38
Venezuela	41	Out of TOP 50

Table 2: FIH world rankings
Source: FIH website **[9]**

4. Methodology

4.1. Design of the supply chain and the product

When defining the sub-minister chain of a product, the most important thing is to know what product you want to produce, with all its variants. From there, the steps to be taken to design the supply chain for the chosen products are presented along the following sections.

The product chosen is the hockey stick, but the important thing is to know what type of stick, what variants should be manufactured and what is the segment that is intended to arrive with each of the variants. The scope of the company is defined by the activities it will carry out, which are as follows:

1. The production of the sticks, which will be made with raw materials of the highest quality.

2. The finish and paint of the sticks, with the proper packaging. Each made stick will be placed in a plastic bag to protect it from possible defects and to transport the sticks cardboard boxes will be used.

3. The distribution of the sticks, once manufactured and packaged, will be made to end customers or retailers depending on the results of the analysis to be carried out later in the section of the distribution network.

4.1.1. Products and variants

One of the most important issues is to define very good the variants of the product that is intended to be marketed. In the world of field hockey there are many necessary equipment such as shin guards, glove, mouthguard, shoes, over grips...but the company will focus exclusively on the manufacture of sticks.

To define the variants, different hockey brands are analyzed to see how are their main sticks that succeed in the market. The different brands analyzed are the following ones:

- **CANÁRIO HÓQUEI:** Canário Hóquei is the only hockey company that exists in Brazil. It is distributed throughout the various Brazilian states and now intends to spread to Chile. It is a very good reference because it can help to understand the budget and the way of playing from people here in South America.

Figure 22: Canário Hóquei logo
Source: Canário Hóquei website **[10]**

- **BALLING:** This company is one of the most important in Argentina, and it has a big importance since Argentina is the current Olympic champion in the men's team, while the girls are also among the best teams in the world. Hockey in Argentina is a great tradition and there are a lot of people playing there.

Figure 23: Balling hockey logo
Source: Balling hockey website **[11]**

- **ADIDAS:** Although Adidas is one of the largest companies in the world and currently the most important in the world of hockey, it is surprising the fact that it was introduced into the hockey world about 10 years ago. Because of their innovative mentality and because they care about offering a product specially made for the player, Adidas is one of the best references to analyze.

Figure 24: Adidas logo
Source: Flick Hockey website **[12]**

- **MALIK:** Malik is one of the most important brands in Europe and Asia. With the origin in Asia, where Pakistan and India are some of the countries with the most activity in hockey around the world, Malik has been growing up for many years and staying in the hockey elite.

Figure 25: MALIK hockey logo
Source: Malik hockey website **[13]**

In short, with these 4 brands it is possible to get ideas from almost the entire hockey market: CANÁRIO HÓQUEI representing Brazil (the largest country in South America), BALLING representing Argentina (of the best countries around the world hockey), MALIK which has great influence in Europe and Asia, and finally ADIDAS which is the most important brand in the field hockey nowadays and one of the most powerful companies in the world.

The company's short-term goal is to produce only 3 stick variants to have options for all types of players. One will be more focused on beginner players who do not require a really good and expensive stick, the second one will be a stick used by the majority of players (much better but also more expensive), and finally there will be one aimed at the best players. Actually, every player can buy the stick they want, but the higher % carbon fiber supposedly higher level is required, and obviously, more expensive it is. All brands divide the sticks by ranges based on the % carbon, so let's look at the best sticks each brand has in each of those 3 ranges by the following comparatives tables.

	Stick's name	Picture	Composition	Bow	Price
CANÁRIO	Elite		90% Carbon 5% Fiberglass 5% Aramid	Low Bow	555 R$
	Original		75% Carbon 20% Fiberglass 5% Aramid	Low Bow	385 R$
	Tropical		55% Carbon 40% Fiberglass 5% Aramid	Mid Bow	495 R$

Table 3: Canário Hóquei sticks comparation
Source: Canário Hóquei website **[10]**

	Stick's name	Picture	Composition	Bow	Price
BALLING	Cerium 100 Green		97% Carbon 2% Kevlar 1% Aramid	Low Bow	1.000 R$
	Iridium 70 Blue		70% Carbon 25% Fiberglass 3% Kevlar 2% Aramid	Extra Low Bow	685 R$
	Barium 50 Vermi		50% Carbon 45% Fiberglass 3% Kevlar 2% Aramid	Low Bow	535 R$

Table 4: Balling hockey sticks comparation
Source: Balling hockey website **[11]**

	Stick's name	Picture	Composition	Bow	Price
adidas	FLX24 Kromaskin		100% Carbon	Low Bow	1.500 R$
	TX24 Carbon		90% Carbon 5% Fiberglass 5% Aramid	Low Bow	1.200 R$
	LX24 Compo 1		70% Carbon 25% Fiberglass 5% Aramid	Low Bow	865 R$

Table 5: Adidas hockey sticks comparation
Source: Flick Hockey website **[12]**

	Stick’s name	Picture	Composition	Bow	Price
MALIK	Gaucho		90% Carbon 5% Fiberglass 5% Aramid	Low Bow	1.250 R$
	V.I.P.		85% Carbon 10% Fiberglass 5% Aramid	Low Bow	825 R$
	Fresh		50% Carbon 45% Fiberglass 5% Aramid	Extra Low Bow	545 R$

Table 6: Malik hockey sticks comparation
Source: Malik hockey website **[13]**

Having analyzed the different sticks of these brands, now it is time to decide how the three models that are intended to be manufactured here in South America will be. It is important to remember that the demand of hockey sticks in Argentina is similar or higher than the demand of many countries in Europe, but in many countries in South America there is not a huge demand in order to put prices similar to those in Europe. That is why it is important to have Canário Hóquei as a reference. Therefore, it is decided to opt for these 3 sticks:

	Composition	Bow	Price
Model 1	90% Carbon 5% Fiberglass 5% Aramid	Late Bow	750 R$
Model 2	75% Carbon 20% Fiberglass 5% Aramid	Late Bow	600 R$
Model 3	50% Carbon 45% Fiberglass 5% Aramid	Mid Bow	500 R$

Table 7: 3 sticks variants that will be manufactured
Source: Own elaboration

4.1.2. Goals

The short-term goal of the company is to start producing in South America by offering a high-quality product at a competitive price. If the product works very well, there could be a possible expansion to any other country/continent, but that would be a long-term goal.

Another important objective is to get local suppliers, and it means to promote the proximity product of the country where the sticks are going to be manufactured.

Finally, the last goal will be to use reverse logistics to be able to recycle sticks for novice or less professional players. Carbon and glass fiber do not stand out for being a very environmentally friendly material, so reusing the sticks and minimizing waste during the manufacturing process is key to pollute as little as possible.

4.1.3. Potential market

South America is a huge territory with many countries. In almost all those countries there is a hockey federation and the different federations are grouped in the Pan American Hockey Federation, but this federation also contains more countries. In total, the countries that are grouped in the Pan American Hockey Federation are: Argentina, Bahamas, Barbados, Bermuda, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, United States, Guatemala, Guyana, Haiti, Honduras, Jamaica, the Caiman Islands, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Trinidad and Tobago, Uruguay and Venezuela. **[14]**

Figure 26: Pan American Hockey Federation logo
Source: Pan American Hockey Federation website **[14]**

The problem is that the territory of South America is too large to cover everything in short term, so it is necessary to narrow down the territory that should be work on. The countries where hockey is played the most are Argentina followed by Chile, but in Uruguay and

Brazil there are also many players. Therefore, these 4 countries are included in the project, while Paraguay is also added because it has quite a few players and is geographically in the middle.

In addition, these countries have good transport connections between them, while the connections with other countries such as Bolivia, Peru or Colombia are not as good due to the existing geological phenomena (Amazonas, jungle, mountains...). In short, the countries analyzed will be: Brazil, Argentina, Chile, Paraguay and Uruguay, as shown below:

Figure 27: Map of South America with the countries that are going to be analyzed in different colors
Source: D-maps website **[15]**

Currently, the different hockey federations in these countries confirmed the number of players in each country, including men's and women's hockey.

Country	Population	Players	% People playing
Argentina	44.270.000	985.000	2,225%
Chile	18.050.000	190.000	1,053%
Brazil	209.300.000	7.500	0,004%
Paraguay	6.811.000	1.650	0,024%
Uruguay	3.457.000	10.000	0,289%
TOTAL	281.888.000	1.194.150	0,424%

Table 8: Population and hockey players in every country analyzed
Source: Own elaboration

Analyzing Table 8, the percentage of each country is calculated considering the total obtained (1.194.150 players). The result of this calculation is shown below and the great inequality of Argentina with the other countries is observed.

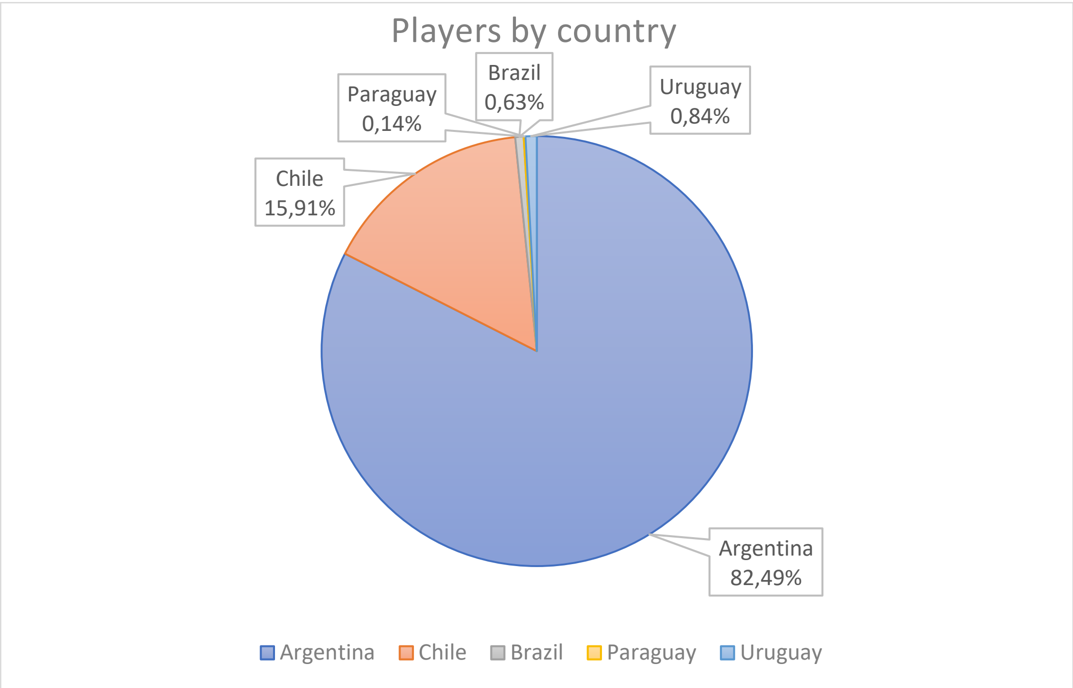


Figure 28: Circular diagram with the percentage of players by country
Source: Own elaboration

Although the percentage of players in Argentina is much higher than the other countries, it should not be forgotten that there are also many players in those countries, simply Argentina is one of the best countries in the world and has a huge number of players.

4.1.4. General structure of the supply chain

According to the defined product and the potential market that is wanted to occupy, the general structure of the supply chain studied will look like the following:

Figure 29: General structure of the supply chain
Source: Own elaboration

The main problem of the suppliers will be to see if all the countries have carbon fiber or fiberglass. With the issue of manufacturing and packaging there is no problem, it is not difficult to make hockey sticks. The most important thing is to find the factory location. With the warehouse it happens exactly the same, how difficult it will be to see where it needs to be located. Finally, the product will be taken through the road to the final customer.

4.2. Forecast

All the methods that are used below have been obtained through the forecasts slides of the *Universitat Politècnica de Catalunya (UPC)*. **[16]**

4.2.1. Choice of the forecast model

To be able to forecast demand, it is first necessary to analyze the components of the demand and know which model to use with the demand that is known. With this prediction model and the historical demand, it will be possible to forecast the demand for the coming years. It is important to know how de demand is changing during the year and how it is growing/decreasing through the years.

Components of de demand:

In the figure shown below, the brown curve represents the demand of the product and all the elements of the demand are represented:

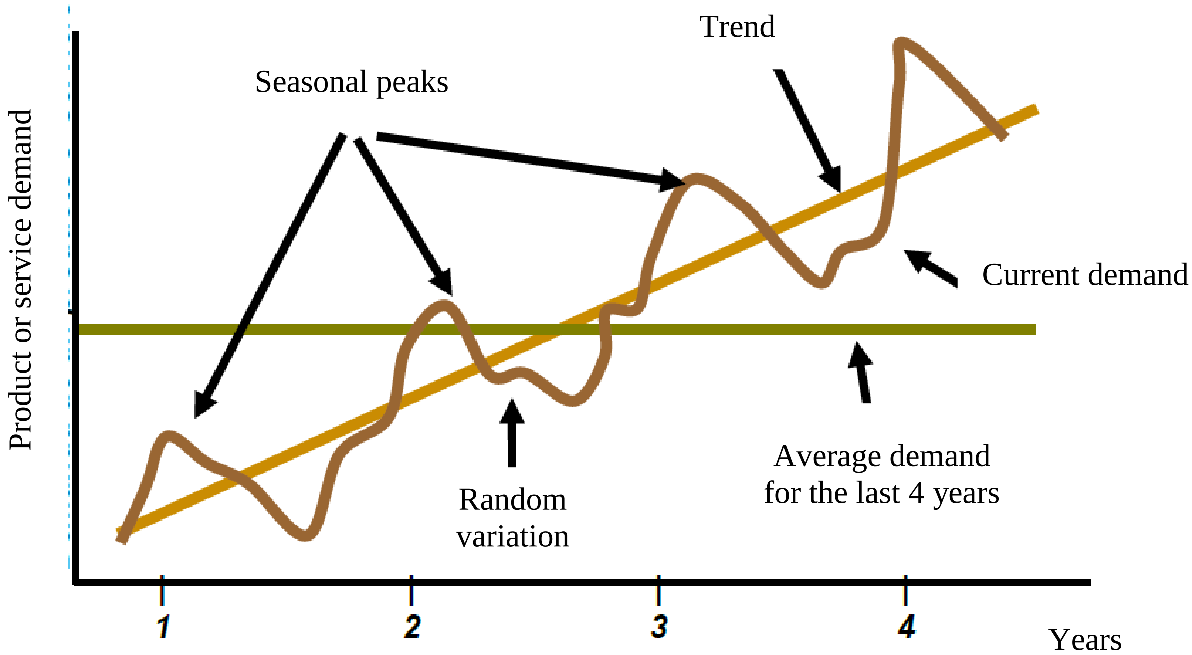


Figure 30: Components of demand
Source: UPC, ETSEIB **[16]**

<u>Forecast models:</u>

On the following picture, it is shown how a forecast model can be. The constant model is only for certain products, while the models with linear tendency and the exponential curve are usually used more. The exponential curve gives more accurate results, but the linear trend model gives very good results and in a simpler way. So, the linear trend model is chosen.

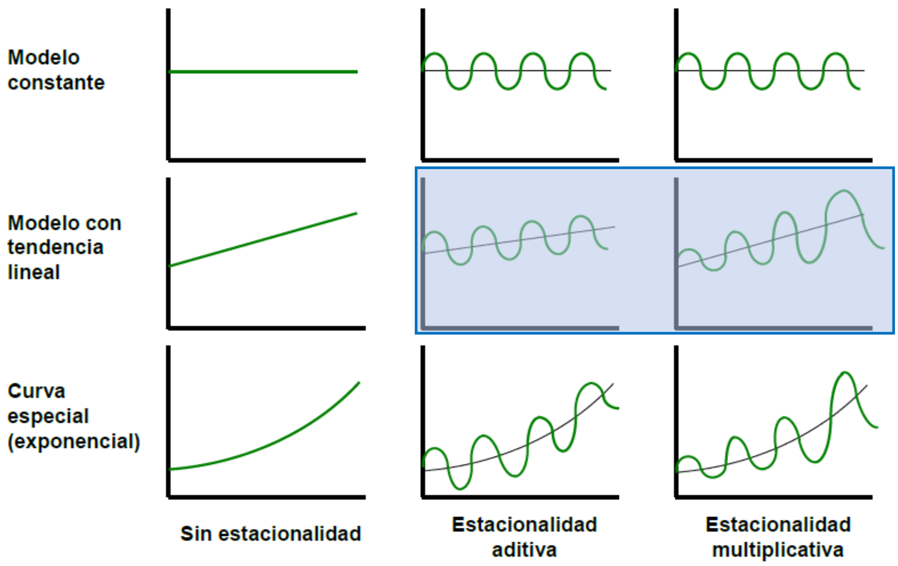


Figure 31: types of regression
Source: UPC, ETSEIB **[16]**

Once the linear trend model has been decided, the big question is as follows: Does the model present additive or multiplicative seasonality? Additive seasonality implies that the demand increases in the same proportion each year, while in the multiplicative seasonality each year the demand increases more in comparison to the previous year.

How to make a forecast?

1. Graphic representation (data: $x_1, x_2, \ldots, x_T$)
2. Identification of the possible model
3. Estimation of model parameters
    - Moving averages
    - Exponential adjustment
    - Linear regression
4. Model verification
5. Application of the model (calculation of forecasts)
6. Update (maintenance) of the model

Models with additive or multiplicative seasonality:

- **Additive seasonality**: the moving average on L observations eliminates the additive seasonal variation (and the multiplicative seasonal variation for constant trend). The 1st moving average (M1) on L observation eliminates the additive seasonality of said model:

$$y_t = f(t) + c_t + \varepsilon_t$$

$$c_t = c_{t-L}$$

$$\sum_{i=1}^{L} c_{t-i} = 0$$

$$\boxed{M_t^{[1]} = \frac{1}{L} \cdot \sum_{k=t-L+1}^{t} x_k}$$

- **Multiplicative seasonality**: The moving average on L observations in the linear trend model transforms the multiplicative seasonality into additive. The 2nd Moving Average (M2) on L observations eliminates the multiplicative seasonality of said model:

$$y_t = f(t) \cdot c_t + \varepsilon_t$$

$$c_t = c_{t-L}$$

$$\sum_{i=1}^{L} c_{t-i} = L$$

$$\boxed{M_t^{[2]} = \frac{1}{L} \cdot \sum_{k=t-L+1}^{t} M_k^{[1]}}$$

Procedure based on the Shiskin method:

1. Graph the X series and determine the type of seasonality

2. Adjust parameters of the trend f(t) with a regression (it can be on the original series or on some of the series of moving averages)
   Correction:

   Additive: $$a' = a + \left(\frac{L-1}{2}\right) \cdot b$$

   Multiplicative: $$a' = a + (L-1) \cdot b$$

3. Determine a first estimation of the L seasonality coefficients

   Additive: $$c_t = x_t - f(t); \quad c_i \rightarrow c_i - \frac{1}{L} \cdot \sum_{k=1}^{L} c_K$$

   Multiplicative: $$c_t = \frac{x_t}{f(t)}; \quad c_i \rightarrow c_i \cdot \frac{L}{\sum_{k=1}^{L} c_K}$$

4. De-seasonalize the X series with the values of the step 2 and obtain a new Y series

   Additive: $$Y_t = x_t - c_t$$

   Multiplicative: $$Y_t = \frac{x_t}{c_t}$$

5. Adjust the values of the parameters of the trend f(t) by means of a regression on the Y series

6. Calculate again the values of the L seasonality coefficients with the trend found in step 4 (idem step 2)

Additive: $$c_t = x_t - f(t); c_i \to c_i - \frac{1}{L} \cdot \sum_{k=1}^{L} c_K$$

Multiplicative: $$c_t = \frac{x_t}{f(t)}; c_i \to c_i \cdot \frac{L}{\sum_{k=1}^{L} c_K}$$

7. Iterate until the coefficients in two consecutive iterations are similar, return to step 3 with the last L coefficients found

8. Final correction:

Additive: $$a' = a + \frac{1}{L} \cdot \sum_{k=1}^{L} c_k ; b' = b$$

Multiplicative: $$a' = a \cdot \frac{\sum_{k=1}^{L} c_k}{L}; b' = b \cdot \frac{\sum_{k=1}^{L} c_k}{L}$$

Comparison between forecast models:

To compare two models, MAD and MSE are usually used. These errors calculate the difference between the data (X) and the prediction made by the model (Y). Therefore, to know if the additive or multiplicative model is better, what is done is to calculate the error in the two models. The one with the lowest errors will be the model that best fits the demand.

- MAD (Mean Absolute Deviation):
  $$\text{MAD}=\left[\sum_{i=1}^{K} |x_i - y_i|\right]/\text{K}$$

- MSE (Mean Squared Error)
  $$\text{MSE}=\left[\sum_{i=1}^{K} (x_i - y_i)^2\right]/\text{K}$$

The MSE is the most used because it penalizes major errors more than proportionally. Better to have a model with moderate errors than one with large or small errors. Normally the two measures are consistent.

4.2.2. Historic demand

In this section we will calculate the historical demand that will be used later to test if the additive or multiplicative model works better to make the forecast of the demand for the next years. To obtain the historical demand is very difficult, and even more for a product not very famous around the world (and even less in South America), so a few simplifications and extrapolation were made. All the process is shown below.

A survey of 65 people was conducted through a Google form. One of the results was the budget that the players had when they buy a stick. The entire survey is in the Annex A, but players from Argentina, Brazil and, mostly, from Spain participated. The following table shows the budget that each percentage of players is willing to pay:

Percentage of customers	Budget
54,70%	100-200 €
25%	200 - 300 €
14,10%	< 100 €
6,20%	300-400 €

Table 9: Percentage of customers for each budget
Source: Own elaboration, Annex A

Therefore, it is established that the average purchase price (P) is the next one:

P= 0,547·150€ +0,25·250€+0,141·50€`0,062·350€=173,3€ (=**745 R$)**

To calculate the sale of sticks in recent years the data from one of the stores that monopolize hockey in Spain is used. The net amount of turnover is obtained through the SABI website (Iberian Balance Sheet Analysis System). This net amount is multiplied for 0,8 because the proportional percentage of the sticks sales is 80% of the total amount. Then, this number of sales is divided by P (average purchase price for a stick, 745 R$).

Year	2018	2017	2016	2015
Net amount sales figure	€ 812.123,00	€ 775.984,00	€ 461.049,00	€ 405.851,00
Proportional percentage of the sticks (~80%)	€ 649.698,40	€ 620.787,20	€ 368.839,20	€ 324.680,80
Number of sticks	3.749	3.582	2.128	1.874

Table 10: Number of sticks sold in the last 4 years
Source: Own elaboration. SABI **[17]**

In Spain, according to the Spanish hockey federation, there are 20,000 players. In this project we work with 1,194,150 players in total (Table 8), so the proportion of this information is made for South America:

1.194.150 / 20.000 = 59,71 → South America has 59,71 times more players than Spain, so the table above is multiplied for 59,71.

Year	2018	2017	2016	2015
Number of sticks sold in South America	223.852	213.890	127.082	111.868

Table 11: Number of sticks sold in South America
Source: Own elaboration

Finally, to calculate the forecasts by quarters, the sale of sticks is divided into percentages according to the quarter, since there are times when you buy more than others:

1st quarter	30%
2nd quarter	10%
3rd quarter	25%
4th quarter	35%

Table 12: Percentage of sales for each quarter
Source: Canário Hockey owner

The historical demand (in number of sticks) that has been generated in recent years is the one shown below. It multiplies Table 11 for the percentage that appear on Table 12.

2018	67.155	1st quarter
	22.385	2nd quarter
	55.963	3rd quarter
	78.348	4th quarter
2017	64.167	1st quarter
	21.389	2nd quarter
	53.473	4th quarter
	74.862	4º quarter
2016	38.125	1st quarter
	12.708	2nd quarter
	31.771	3rd quarter
	44.479	4th quarter
2015	33.560	1st quarter
	11.187	2nd quarter
	27.967	3rd quarter
	39.154	4th quarter

Table 13: Demand of sticks on the last years
Source: Own elaboration

The result of the forecast model is shown in chapter 5.1.

4.3. Capacity planning

All the methods that are used below have been obtained through the capacity planning slides of the *Universitat Politècnica de Catalunya (UPC)*. **[18]**

4.3.1. Mathematical model to optimize production planning

Once the demand forecast for next year has been obtained, the next thing to do is calculate the capacity. Production is planned for the next 12 months using the IBM CPLEX optimization program (the code is in the Annex B). The mathematical model used to plan the production, stock and capacity of the year 2020 is the one shown below:

We want to plan the production of the hockey sticks for each of the following T periods, considering:

1. The demand must be delivered in each period (the demand is known, D_t)
2. The product can be stored, and the capacity of the warehouse is CS units
3. There is a fixed production capacity (K_t, in units), which can increase for an additional cost of c_t (R$ / u) capacity. For example, this capacity could be working during the night or during weekends. Of course, the price of c_t is much higher than the usual cost of production.
4. It is necessary to consider the costs of production (cp_t, R$ / u), additional capacity (c_t, R$ / u), stock (cs_t, R$ / u and period)
5. We know the sales price in each period, sp_t (R$/u)

<u>Data:</u>

- T periods
- D_t → Demand [units] (t=1…T)
- CS → Storage capacity [units]
- K_t → Production capacity [units] (t=1…T)
- cp_t → Production cost [R$/u] (t=1…T)
- c_t → Additional capacity cost [R$/u] (t=1…T)
- cs_t → Storage cost [R$/u] (t=1…T)
- sp_t → Sales price [R$/u] (t=1…T)

Variables:

- S_t → Stock for the period t [units] (t=1…T)
- x_t → Production for the month t [units] (t=1…T)
- ce_t → Extra capacity used on the month t [units] (t=1…T)

Objective Function:

[MAX] Benefit = $\sum_{t=1}^{T}[\ (pv_t \cdot D_t) - (\,cp_t \cdot x_t + cs_t \cdot S_t + c_t \cdot ce_t)]$

Restrictions:

$$x_t, S_t, ce_t \ \geq 0 \qquad t = 1 \ldots T$$
$$S_{t-1} + x_t = D_t + S_t$$
$$x_t \leq K_t + ce_t$$

4.3.2. Monthly demand calculation

Thanks to the sales forecast model, demand can be calculated for the next 4 quarters of 2020. Once the demand for each semester has been calculated, it is important to decide the market share that it is intended to have. Normally the market share is usually very low because you must consider that it is not easy to enter a new market. This market share will increase if the company works, but to begin with, it is considered that a market share of 5% is already optimistic and enough.

Year	Quarter	Demand	Market share = 5%
2020	1	88.305	4.415
	2	28.367	1.418
	3	68.695	3.435
	4	93.537	4.677

Table 14: Demand trying to be satisfied for each quarter of 2020
Source: Own elaboration

Now that we have the demand per quarter, we decide to divide it into the 12 months of the year to facilitate the calculation of the production plan.

Year	Mont	% Relevance	Demand
2020	January	50%	2.208
2020	February	30%	1.325
2020	March	20%	883
2020	April	30%	426
2020	May	40%	567
2020	June	30%	426
2020	July	20%	687
2020	August	10%	343
2020	September	70%	2.404
2020	October	40%	1.871
2020	November	20%	935
2020	December	40%	1.871

Table 15: Demand per month (2020)
Source: Own elaboration, Canário Hóquei owner

This demand is represented in figure 32 that is shown below:

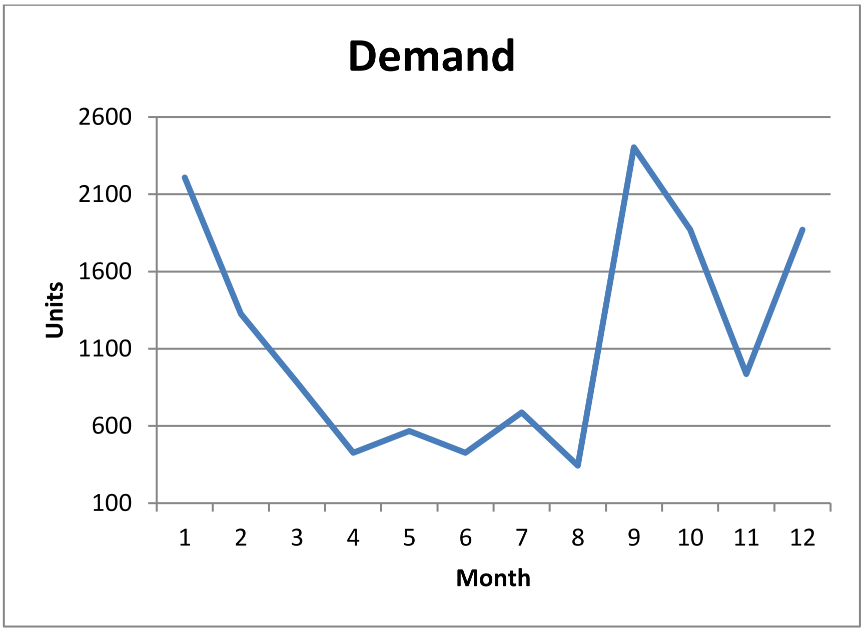


Figure 32: Demand per month (2020)
Source: Own elaboration

The result of the mathematical model is shown in chapter 5.2

4.4. Location

All the methods that are used below have been obtained through the location slides of the *Universitat Politècnica de Catalunya (UPC)*. **[19]**

The decision-making process of the location of the factory can be done following the following steps:

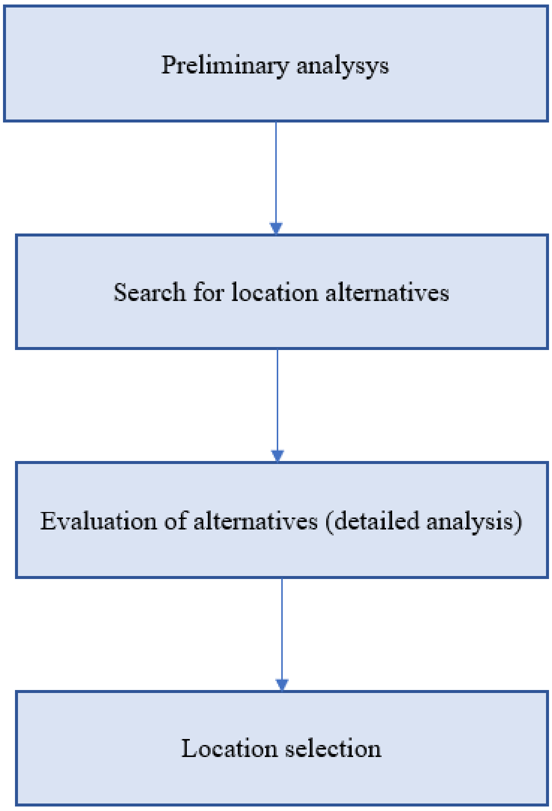


Figure 33: decision-making process of the location for a factory
Source: UPC, ETSEIB **[19]**

Qualitative methods

- Industrial background: the new facility is located near other similar facilities.
- Preferential factor: the decision maker has a predilection (which does not have to be based on objective criteria) for a specific location.
- Predominant factor: there is a dominant criteria that restricts the possibilities of location.
- Methods of multicriteria decision: there are several criteria of diverse importance and not always comparable in the decision making.

Here there is a table with different criteria when choosing a location:

Proximity to sources of supply	Local policies (legal and tax)	Availability and cost of homes and buildings in general
Markets	Space (availability and cost) for expansion	Proximity of certain services (schools, universities, markets, research centers ...)
Means of transport and communications	Opportunity to combine with existing facilities	Attitudes towards the company (authorities and community)
Offer, level and cost of labor	Supply of energy, water, fuel	Living conditions (education, cost of living, security, climate ...)
Possibility of conserving the current workforce	Possibility of getting rid of waste and waste	Climate (impact on processes and costs)
Relationship between workers and company	Favorable experiences of similar facilities	Political, social and economic stability

Table 16: Examples of criteria when choosing a location
Source: UPC, ETSEIB **[19]**

Problems in the application of criteria:

- Criteria are valued in very different ways:
    - In monetary terms (costs, income, profitability, benefits ...)
    - In time (displacement, construction ...)
    - In more complex units (available surface, capacity ...)
    - Qualitatively (trust, position of local politicians, climate ...)
    - Through a complex report (geological study, market study ...)
    - Etc.
- The criteria may or may not be comparable
- Criteria may or may not be hierarchical
- The criteria can be objective or subjective
- The criteria may vary over time

4.4.1. Brown & Gibson method

The method that will be used to decide the location is the Brown & Gibson method. This method is perfect to combine quantifiable factors with subjective factors that are evaluated in subjective terms.

There are three types of factors:

- **Critical factors (CF)**: they are key factors for the functioning of the organization. Its rating is binary: 1 implies that the location satisfies the critical factor.
- **Objective factors (OF):** can be quantified in monetary terms (example: costs of production, maintenance, construction, raw materials ...)
- **Subjective factors (SF):** qualitative but that significantly affect the operation of the company

Process of the Brown and Gibson method

1. Remove locations that do not accomplish the critical requirements → there are *n* locations left.

2. Calculate the objective factor of each location ($OF_i, i = 1, \dots, n$). Usually these costs are the relevant costs of the location (salary, rent, water, energy, etc.).

$$OF_i = \frac{\frac{1}{Ct_i}}{\sum_{i=1}^{n} \frac{1}{Ct_i}}$$

3. Determine the key subjective factors and estimate their weighting for each location according to:

    a. Estimate the weight of each factor w_j comparing them two to two, deciding if one factor has more weight than another or they are equal; values $w'_{jk} = 0$ (*j* less important than *k*) o 1 (*j* equal or more important than *k*):

    $$w'_{jj} = 0 \rightarrow w_j = \frac{\sum_{k=1}^{K} w'_{jk}}{\sum_{j=1}^{K} \sum_{k=1}^{K} w'_{jk}}$$

    b. Assign a score R_{ij} for each location *i* and factor *j* (*i*=1, …,*n*; *j*=1, …, *K*) comparing locations two to two (analogous to weights, see example).

c. Combine, for each location, the weight of the factor (w_j) and the R_{ij} assigned:

$$SF_i = \sum_{j=!}^{K} w_j \cdot R_{ij}$$

d. Obtain the preference index for each location, weighting the objective and subjective factor. Usually, the objective factor is more important, so α usually is higher than 0,5.

$$IL_i = \alpha \cdot OF_i + (1 - \alpha) \cdot SF_i$$

<u>Example of the Brown and Gibson method:</u> A new steel sheet factory must be located. The preliminary study indicates that the best locations are in (A, B and C) for access to raw materials and communication networks.

The annual cost of production between the locations differs in the cost of labor, distribution and taxes:

Annual cost (millions R$)							
i	Cost of labor	Distribution	Taxes	Others	Ci	1/Ci	OF_i
A	3,62	2,80	0,25	4,00	10,67	0,094	0,335
B	3,40	2,75	0,30	4,00	10,45	0,096	0,342
C	3,75	2,90	0,40	4,00	11,05	0,090	0,323
					TOTAL	0,280	1,000

Table 17: Example. Calculate objective factors
Source: UPC, ETSEIB **[19]**

The subjective factors identified have been: habitability, education, relationship with the community.

- A weight must be assigned to each factor (w_j)
- And for each factor a score for each location

Factor j	Comparisons			Sum of preferences	Relevance w_j
	E	H	C		
Education (1)	1	1	0	2	2/7=0,825
Habitability (2)	1	1	0	2	0,285
Community (3)	1	1	1	3	0,428
			TOTAL	7	1

Table 18: Example. How to calculate the weight for each subjective factor
Source: UPC, ETSEIB **[19]**

For each subjective factor, the same pairwise comparison between locations is established:

Education					
1	A	B	C	sum	R_{i1}
A	1	1	1	3	0,428
B	0	1	1	2	0,285
C	0	1	1	2	0,285
			TOTAL	7	1

Habitability					
2	A	B	C	sum	R_{i2}
A	1	0	1	2	0,285
B	1	1	1	3	0,428
C	1	0	1	2	0,285
			TOTAL	7	1

Community					
3	A	B	C	sum	R_{i3}
A	1	0	0	1	0,167
B	1	1	0	2	0,333
C	1	1	1	3	0,500
			TOTAL	6	1

Table 19: Example. Pairwise comparison for each subjective factor
Source: UPC, ETSEIB **[19]**

	R_{Aj}	R_{Bj}	R_{Cj}	w_j
Education	0,428	0,285	0,285	0,285
Habitability	0,285	0,428	0,285	0,285
Community	0,167	0,285	0,428	0,428
SF_i	0,275	0,325	0,346	

Table 20: Example. Subjective factors for each location
Source: UPC, ETSEIB **[19]**

For example, SF_A is calculated with this formula:

$$SF_A = R_{A1} \cdot w_1 + R_{A2} \cdot w_2 + R_{A3} \cdot w_3$$

$$SF_A = 0{,}428 \cdot 0{,}285 + 0{,}285 \cdot 0{,}285 + 0{,}167 \cdot 0{,}428$$

$$SF_A = 0{,}275$$

Finally, the objective factors and the subjective factors are combined to see which location is the best:

$$IL_i = \alpha \cdot OF_i + (1 - \alpha) \cdot SF_i$$

i	OF_i	SF_i
A	0,335	0,275
B	0,342	0,325
C	0,323	0,346

Table 21: Objective and subjective factors for each location
Source: UPC, ETSEIB **[19]**

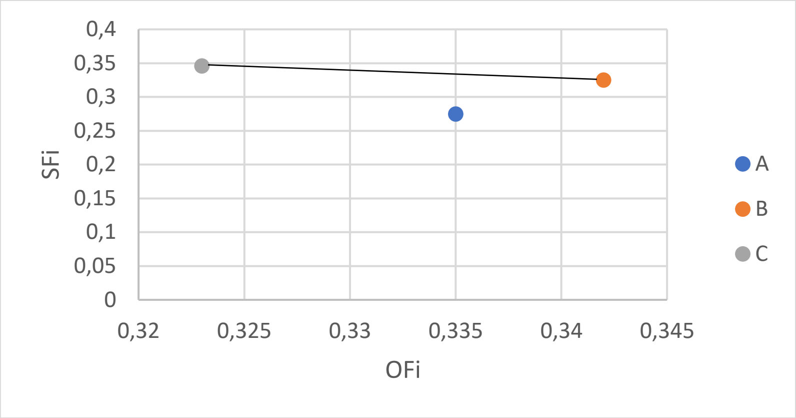


Figure 34: Graphic representation: Objective factors vs. Subjective factors
Source: UPC, ETSEIB **[19]**

A is dominated.

For $\alpha \geq 0{,}525$ the best option is B (better than C)

4.4.2. Preliminary analysis of alternatives

As discussed in previous chapters, the alternatives in this Brown & Gibson model are the following:

- Argentina: one of the most important field hockey countries in the world.
- Brazil: huge population, getting bigger and bigger every year in the field hockey world.
- Chile: second best country in South America.
- Paraguay: Geographically close, not very important playing hockey but still a nice target.
- Uruguay: usually the third country in South America. Now fighting with Brazil for this third place.

4.4.3. Description and analysis of decision factors

Now it is time to analyze the factors in this model.

4.4.3.1. Critical factors (CF)

The critical factors are:

- Energy supply (ES)
- Water supply (WS)
- Workforce (WF)
- Raw material (RM)

For each location, the CF will be:

$$CF_i = \text{ES} \cdot \text{WS} \cdot \text{WF} \cdot \text{RM} = \{1{,}0\}$$

If some of those factors doesn't exist in any of the location, that location will have a CF=0 because ES, WS, WF and RM are binary and can only be 1 or 0. In this case, that location would be out of the study.

4.4.3.2. Objective factors (OF)

The objective factors associated with the location of the company are the cost of labor and the rent of the industrial building. The values of these costs are in chapter 5.3.

4.4.3.3. Subjective factors (SF)

The subjective factors are:

- Proximity to customers (P)
- Communications and transport (CT)
- Taxes (T)
- Competitors (C)
- Security (S)
- Social climate (SC)

4.5. Distribution

All the methods that are used below have been obtained through the distribution slides of the *Universitat Politècnica de Catalunya (UPC)*. **[20]**

We understand by distribution all those necessary steps to move and store a product from the supplier to the customer. The distribution is a key factor in the overall profitability of the company, as it affects the cost of the supply chain and customer satisfaction. Each company designs a distribution structure based on the objectives of the company and its strategy. In order to decide on a good distribution network, there must be two basic objectives: to meet the client's needs and reduce the cost of satisfying those needs.

Once the final location of the production plant is defined, in Argentina, the next objective is to determine where to store the stock. Due to the size of the company and the expected demand, it is not considered necessary to have more than one warehouse. But the big question is: where should this warehouse be located? In order to carry out this analysis, each of the countries is represented by its capital since it is where there is the greatest activity of hockey and commercial in general. In the case of Brazil, the chosen city is São Paulo because it is very important and closer to the rest of the countries. Assuming that any of the options will meet the entire demand, the main objective is to reduce costs. The capitals are: Buenos Aires (Argentina), Montevideo (Uruguay), São Paulo (Brazil), Asunción (Paraguay) and Santiago de Chile (Chile).

4.5.1. Analysis and choice of the best distribution model

In order to realize a mathematical model that minimizes costs and what is the best location of the warehouse, the number of customers in each of the established areas (Argentina, Brazil, Chile, Paraguay and Uruguay) must be very clear.

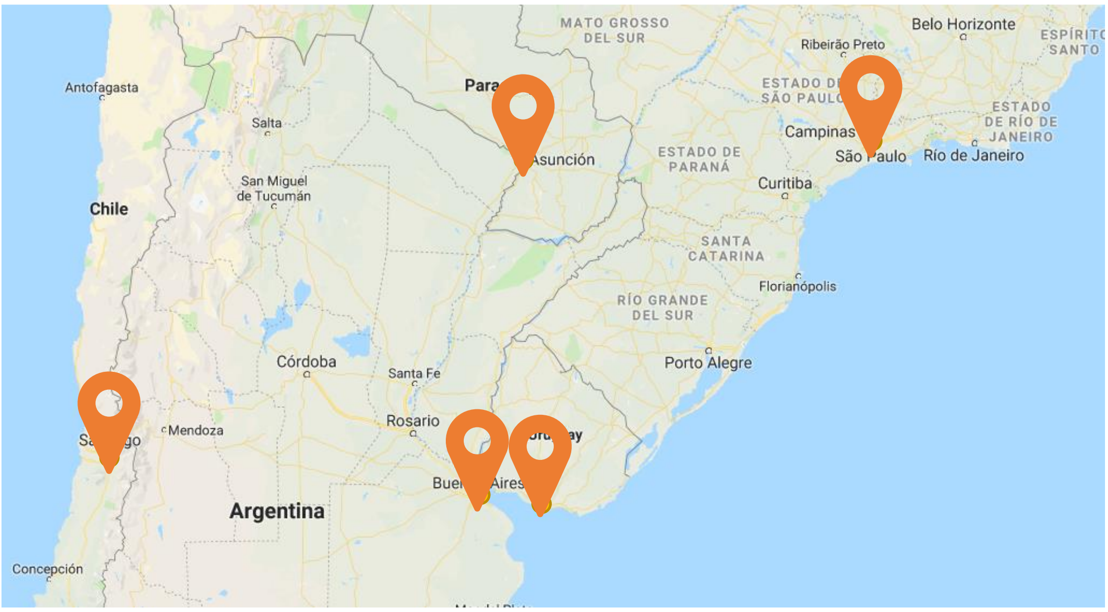


Figure 35: Location of the main cities
Source: Google maps **[21]**

According to the market share of 5% and forecasts made with the model, the prediction of sale of sticks is 13,945 sticks. If we distribute this value by the percentage corresponding to each country (see Figure 28) we obtain the following number of customers per country.

fi	Customers
Brazil	88
Argentina	11501
Chile	2219
Uruguay	117
Paraguay	20

Table 22: Customers per country
Source: Own elaboration

4.5.2. Configuration of a distribution network that minimizes transport costs

As for the mathematical model, the main objective is to reduce the costs of the distribution network. Two types of costs will be studied:

- **Fixed costs:** They are the associates in the annual rent of a warehouse in each one of the countries. Here the rent is half of the price we had for the 1.000m^2 factory. With 500m^2 is enough for a warehouse.

(Per year)	Rent [R$]
Brazil	5.000
Argentina	6.850
Chile	7.300
Uruguay	6.150
Paraguay	4.750

Table 23: Annual rent for each country for a 500m^2 warehouse
Source: Own elaboration

- **Variable costs:** The variable costs refer to the transport between the different locations. The matrix of distances is shown below (Table 24), and the cost of the km is 2.15 R $ / km.

Dist. (km)	Brazil	Argentina	Chile	Uruguay	Paraguay
Brazil	-	2.234	3.288	1.938	1.347
Argentina	2.234	-	1.455	588	1.261
Chile	3.288	1.455	-	1.925	2.132
Uruguay	1.938	588	1.925	-	1.509
Paraguay	1.347	1.261	2.132	1.509	-

Table 24: Matrix of distances between the main cities of each country
Source: Google maps **[21]**

With this matrix of distances and the price of 2.15 R$/km, it is necessary to transform the matrix of distances into the matrix of variable costs.

R$	Brazil	Argentina	Chile	Uruguay	Paraguay
Brazil	-	4.803,1	7.069,2	4.166,7	2.896,05
Argentina	4.803,1	-	3.128,35	1.264,2	2.711,15
Chile	7.069,2	3.128,35	-	4.138,75	4.583,8
Uruguay	4.166,7	1.264,2	4.138,75	-	3.244,35
Paraguay	2.896,05	2.711,15	4.583,8	3.244,35	-

Table 25: Matrix of variable costs
Source: Own elaboration

It has been considered that between a location and itself (the elements of the diagonal) the distance can be neglected.

The **parameters** are the following:

- n → number of possible production plants
- m → number of demand areas
- D_j → demand of area j
- C_{ij} → cost of sending a stick from i to j
- f_i → fixed annualized cost of keeping the factory i open
- K_i → capacity of the plant i

The **variables** are the following:

- X_{ij}: binary variable. It is 1 if i serves j.
- Y_i: binary variable. It is 1 if we open a warehouse in i.

The **objective function** is the following:

$$Min \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij}$$

This objective function aims to minimize the sum of the fixed costs and the variable costs. The first term refers to the fixed costs: there is a fixed cost in the country i equal to f_i if $Y_i = 1$.

On the other hand, the second term refers to the variable costs that exist between the different locations. C_{ij} is the matrix of distances multiplied by the 2.15 R $ / km and X_{ij} indicates that the client i serves the client j.

The existing restrictions, therefore, are:

$$\sum_{i=1}^{n} x_{ij} = 1$$

$$\sum_{j=1}^{n} D_j x_{ij} \leq K_i y_i$$

- All the demand must be satisfied
- Only one warehouse can be used
- All countries must be satisfied

4.5.3. Methods of transport to use

The transport to be used will be outsourced and reduced to the use of trucks by road.

4.6. Reverse logistics

Carbon fiber and fiberglass are materials that can not be recycled and are not the most sustainable in the world. But one thing you can do is reuse old sticks to reduce the manufacture of sticks and thus contaminate less.

Nowadays, a lot of people change the stick to buy a new one and stop using the old one. Maybe if you get a small amount of money, the players would give the old sticks so they can be reused. The company would analyze which sticks are in good condition and they would be painted again, added a new grip or change everything that is needed.

The problem is: how to transport the stick from each country to the main factory + warehouse? The thing is that the trucks that brings the sticks to every country, they can pick the old sticks there and bring them back to the factory. If the stick is in good conditions, it will be reused, and if it is not, it would be give it back to the owner on the next truck going to the original country.

5. Description of the results

5.1. Forecast

The Shiskin method explained in section 4.2.1 is used to calculate the forecast model.

5.1.1. Additive Model

Year	Quarter (t)	x(t)	M1	M2
2015	1	33.560		
2015	2	11.187		
2015	3	27.967		
2015	4	39.154	27.967	
2016	5	38.125	29.108	
2016	6	12.708	29.488	
2016	7	31.771	30.439	29.251
2016	8	44.479	31.771	30.202
2017	9	64.167	38.281	32.495
2017	10	21.389	40.451	35.236
2017	11	53.473	45.877	39.095
2017	12	74.862	53.473	44.521
2018	13	67.155	54.220	48.505
2018	14	22.385	54.469	52.009
2018	15	55.963	55.091	54.313
2018	16	78.348	55.963	54.936

Table 26: Year, quarter, demand and mobile averages M1 and M2
Source: Own elaboration

1. Graph the X series and determine the type of seasonality

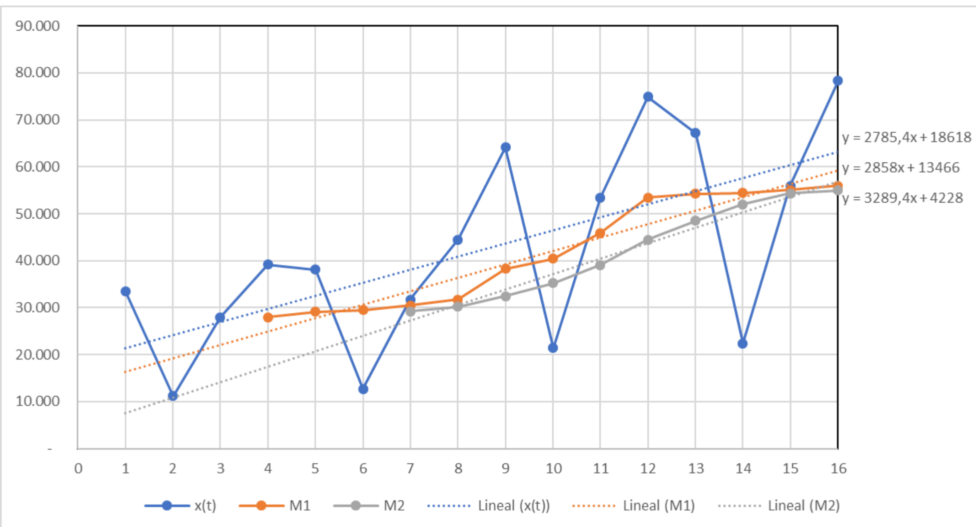


Figure 36: Units of sticks demanded every quarter. Averages mobiles are represented as well
Source: Own elaboration

In this figure you can see the demand (series x (t)) and mobile medians (M1 orange and M2 gray). It is very hard to see which one fits better the x(t) trend, so it is necessary to calculate both models and then see which one has less deviation.

2. Adjust parameters of the trend f(t) with a regression (it can be on the original series or on some of the series of moving averages)

   Correction:

   Additive: $$a' = a + \left(\frac{L-1}{2}\right) \cdot b$$

From the figure 36 it is possible to get the regression line of the 1st moving average (M1). It is the next one:

$$f(t) = a + b \cdot t = 13466 + 2858 \cdot t$$

So, a = 13466 and b = 2858. The problem is that in this step 2 of Shiskin Method it is necessary to adjust a.

$$a' = a + \left(\frac{L-1}{2}\right) \cdot b = 13466 + \left(\frac{4-1}{2}\right) \cdot 2858 = 17753$$

$$f'(t) = a' + b \cdot t = 17753 + 2858 \cdot t$$

3. Determine a first estimation of the L seasonality coefficients

   Additive: $$c_t = x_t - f(t); \quad c_i \to c_i - \frac{1}{L} \cdot \sum_{k=1}^{L} c_K$$

Year	Quarter (t)	*x(t)*	*M1*	*M2*	*f'(t)*	*C(t)=x(t)-f'(t)*
2015	1	33.560			20.611	12.949
2015	2	11.187			23.469	- 12.282
2015	3	27.967			26.327	1.640
2015	4	39.154	27.967		29.185	9.969
2016	5	38.125	29.108		32.043	6.082
2016	6	12.708	29.488		34.901	- 22.193
2016	7	31.771	30.439	29.251	37.759	- 5.988
2016	8	44.479	31.771	30.202	40.617	3.862
2017	9	64.167	38.281	32.495	43.475	20.692
2017	10	21.389	40.451	35.236	46.333	- 24.944
2017	11	53.473	45.877	39.095	49.191	4.282

2017	12	74.862	53.473	44.521	52.049	22.813
2018	13	67.155	54.220	48.505	54.907	12.248
2018	14	22.385	54.469	52.009	57.765	- 35.380
2018	15	55.963	55.091	54.313	60.623	- 4.660
2018	16	78.348	55.963	54.936	63.481	14.867

Table 27: *f'(t)* and *L* are added to the table
Source: Own elaboration

	c1(t) Average	Adjusted
1st quarter	12.993	12.746
2nd quarter	- 23.700	- 23.947
3r quarter	- 1.182	- 1.429
4th quarter	12.878	12.630
TOTAL	989	0

Table 28: *c1(t)* adjusted
Source: Own elaboration

4. De-seasonalize the X series with the values of the step 2 and obtain a new Y series

Additive: $Y_t = x_t - c_t$

Year	Quarter (t)	x(t)	c1(t)	Y(t)=x(t)-c1(t)
2015	1	33.560	12.746	20.815
2015	2	11.187	- 23.947	35.134
2015	3	27.967	- 1.429	29.396
2015	4	39.154	12.630	26.523
2016	5	38.125	12.746	25.379
2016	6	12.708	- 23.947	36.655
2016	7	31.771	- 1.429	33.200
2016	8	44.479	12.630	31.849
2017	9	64.167	12.746	51.421
2017	10	21.389	- 23.947	45.336
2017	11	53.473	- 1.429	54.902
2017	12	74.862	12.630	62.231
2018	13	67.155	12.746	54.410
2018	14	22.385	- 23.947	46.332
2018	15	55.963	- 1.429	57.392
2018	16	78.348	12.630	65.718

Table 29: Y(t) series
Source: Own elaboration

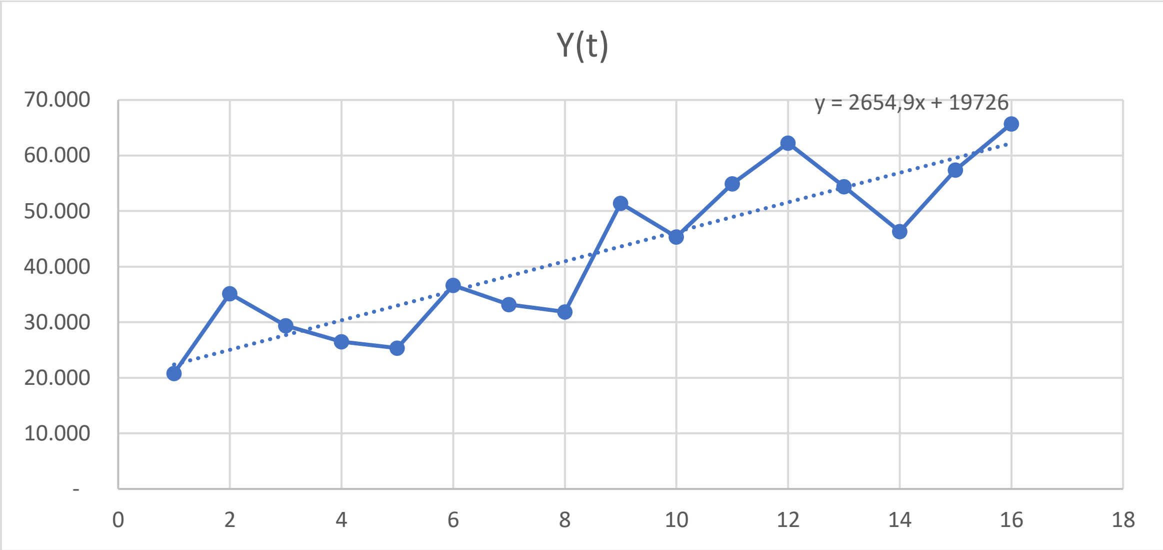


Figure 37: Y(t) series
Source: Own elaboration

5. Adjust the values of the parameters of the trend f(t) by means of a regression on the Y series

$$f2(t) = 19726 + 2654{,}9 \cdot t$$

6. Calculate again the values of the L seasonality coefficients with the trend found in step 4 (idem step 2)

Additive: $$c_t = x_t - f(t); c_i \to c_i - \frac{1}{L} \cdot \sum_{k=1}^{L} c_K$$

Year	Quarter (t)	x(t)	f2(t)	C(t)=x(t)-f2(t)	c2(t)
2015	1	33.560	22380,9	11.179	12.441
2015	2	11.187	25035,8	- 13.849	- 24.049
2015	3	27.967	27690,7	276	- 1.327
2015	4	39.154	30345,6	8.808	12.935
2016	5	38.125	33000,5	5.124	12.441
2016	6	12.708	35655,4	- 22.947	- 24.049
2016	7	31.771	38310,3	- 6.540	- 1.327
2016	8	44.479	40965,2	3.514	12.935
2017	9	64.167	43620,1	20.547	12.441
2017	10	21.389	46275	- 24.886	- 24.049
2017	11	53.473	48929,9	4.543	- 1.327
2017	12	74.862	51584,8	23.277	12.935
2018	13	67.155	54239,7	12.916	12.441
2018	14	22.385	56894,6	- 34.509	- 24.049
2018	15	55.963	59549,5	- 3.587	- 1.327
2018	16	78.348	62204,4	16.144	12.935

Table 30: *f2(t)* and *c2(t)*
Source: Own elaboration

7. Iterate until the coefficients in two consecutive iterations are similar, return to step 3 with the last L coefficients found

Relative error between c1(t) y c2(t)
2,45%
0,42%
7,65%
2,36%
2,45%
0,42%
7,65%
2,36%
2,45%
0,42%
7,65%
2,36%
2,45%
0,42%
7,65%
2,36%

Table 31: Relative error between *c1(t)* and *c2(t)*
Source: Own elaboration

In this first iteration, the deviation between c1(t) and c2(t) is too big. At least it should be under 5% of relative deviation. So, it is necessary to iterate again. The results from the second iteration are the following ones:

Year	Quarter (t)	x(t)	Y'(t)	f3(t)	C(t)=x(t)-f3(t)	c3(t)	error entre c2(t) y c3(t)
2015	1	33.560	21.119	22471	11.089	12.423	0,14%
2015	2	11.187	35.235	25114	- 13.927	- 24.054	0,02%
2015	3	27.967	29.294	27757	210	- 1.322	0,45%
2015	4	39.154	26.219	30400	8.754	12.953	0,14%
2016	5	38.125	25.684	33043	5.082	12.423	0,14%
2016	6	12.708	36.757	35686	- 22.978	- 24.054	0,02%
2016	7	31.771	33.098	38329	- 6.558	- 1.322	0,45%
2016	8	44.479	31.544	40972	3.507	12.953	0,14%
2017	9	64.167	51.726	43615	20.552	12.423	0,14%
2017	10	21.389	45.438	46258	- 24.869	- 24.054	0,02%
2017	11	53.473	54.800	48901	4.572	- 1.322	0,45%
2017	12	74.862	61.927	51544	23.318	12.953	0,14%
2018	13	67.155	54.714	54187	12.968	12.423	0,14%
2018	14	22.385	46.434	56830	- 34.445	- 24.054	0,02%
2018	15	55.963	57.290	59473	- 3.510	- 1.322	0,45%
2018	16	78.348	65.413	62116	16.232	12.953	0,14%

Table 32: Results from second iteration
Source: Own elaboration

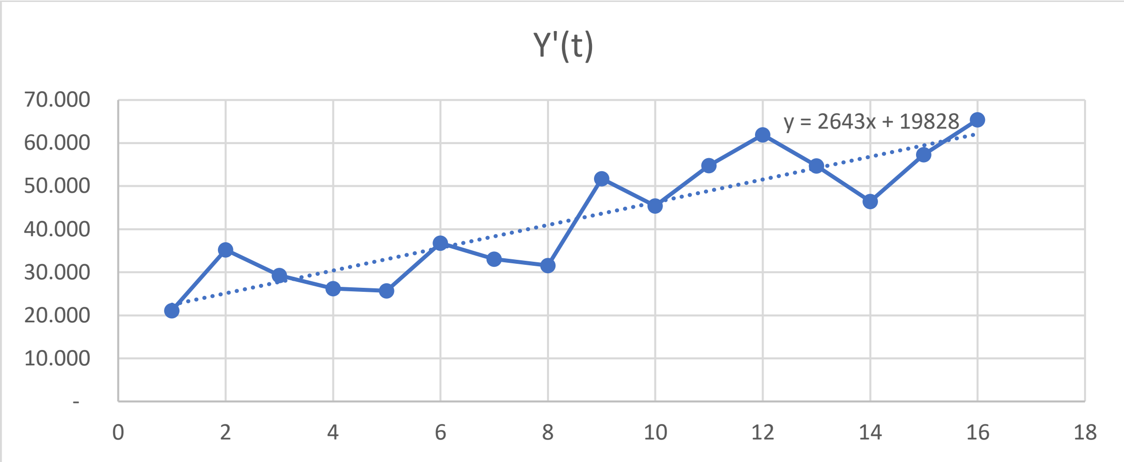


Figure 38: *Y'(t)* resulting from second iteration
Source: Own elaboration

8. Final correction:

Additive: $$a' = a + \frac{1}{L} \cdot \sum_{k=1}^{L} c_k \,;\, b' = b$$

Final correction	Value
a	19828
b	2643
a'	19.828
b'	2643

Table 33: Final correction on parameters *a* and *b* in order to calculate the final *Y(t)*
Source: Own elaboration

Año	Trimestre (t)	x(t)	Y"(t)
2015	1	33.560	34.894
2015	2	11.187	1.059
2015	3	27.967	26.435
2015	4	39.154	43.353
2016	5	38.125	45.466
2016	6	12.708	11.631
2016	7	31.771	37.007
2016	8	44.479	53.925
2017	9	64.167	56.038
2017	10	21.389	22.203
2017	11	53.473	47.579
2017	12	74.862	64.497
2018	13	67.155	66.610
2018	14	22.385	32.775
2018	15	55.963	58.151
2018	16	78.348	75.069

Table 34: Final *Y(t)*
Source: Own elaboration

5.1.2. Multiplicative Model

The entire process with the multiplicative model is found in Annex C. The final result is shown below:

Year	Quarter (t)	x(t)	M1	M2	Y'(t)
2015	1	33.560			29.529
2015	2	11.187			10.240
2015	3	27.967			26.483
2015	4	39.154	27.967		38.186
2016	5	38.125	29.108		44.223
2016	6	12.708	29.488		14.772
2016	7	31.771	30.439	29.251	37.036
2016	8	44.479	31.771	30.202	52.024
2017	9	64.167	38.281	32.495	58.917
2017	10	21.389	40.451	35.236	19.303
2017	11	53.473	45.877	39.095	47.589
2017	12	74.862	53.473	44.521	65.862
2018	13	67.155	54.220	48.505	73.611
2018	14	22.385	54.469	52.009	23.835
2018	15	55.963	55.091	54.313	58.142
2018	16	78.348	55.963	54.936	79.699

Table 35: results of the multiplicative model
Source: Own elaboration

5.1.3. Comparison

Now the deviations from each model are compared to see which one fits the best with the sticks demand:

Quarter	x(t)	Y(t)	|x-y|	$(x-y)^2$
1	33.560	34.894	1.334	1.778.437
2	11.187	1.059	10.127	102.565.712
3	27.967	26.435	1.532	2.346.052
4	39.154	43.353	4.199	17.630.291
5	38.125	45.466	7.341	53.893.025
6	12.708	11.631	1.077	1.159.795
7	31.771	37.007	5.237	27.422.563
8	44.479	53.925	9.446	89.221.589
9	64.167	56.038	8.129	66.083.787
10	21.389	22.203	814	663.034
11	53.473	47.579	5.893	34.731.314
12	74.862	64.497	10.365	107.434.450
13	67.155	66.610	546	297.651
14	22.385	32.775	10.390	107.955.051
15	55.963	58.151	2.188	4.788.898
16	78.348	75.069	3.280	10.755.139
			81.897	628.726.789
			MAD	MSE

Table 36: Errors for Additive model
Source Own elaboration

Quarter	x(t)	Y(t)	|x-y|	$(x-y)^2$
1	33.560	29.529	4.031	16.248.442
2	11.187	10.240	947	896.519
3	27.967	26.483	1.483	2.200.738
4	39.154	38.186	967	935.676
5	38.125	44.223	6.099	37.193.805
6	12.708	14.772	2.063	4.257.571
7	31.771	37.036	5.266	27.726.698
8	44.479	52.024	7.545	56.928.876
9	64.167	58.917	5.250	27.559.417
10	21.389	19.303	2.086	4.350.168
11	53.473	47.589	5.884	34.616.799
12	74.862	65.862	9.000	81.001.847
13	67.155	73.611	6.456	41.678.836
14	22.385	23.835	1.450	2.102.115
15	55.963	58.142	2.179	4.747.359
16	78.348	79.699	1.351	1.825.216
			62.056	344.270.081
			MAD	MSE

Table 37: Errors for multiplicative model
Source: Own elaboration

As you can see, the multiplicative model fits better the demand, so this model is the one that will be used for the forecasts.

5.1.4. Final forecast for the next years

Historical Demand		Forecasts	
Quarter	Y(t)	Quarter	Y(t)
1	29.529	17	88.305
2	10.239	18	28.366
3	26.483	19	68.694
4	38.186	20	93.536
5	44.223	21	102.999
6	14.771	22	32.898
7	37.036	23	79.247
8	52.023	24	107.374
9	58.917	25	117.693
10	19.303	26	37.430
11	47.588	27	89.800
12	65.861	28	121.211
13	73.611	29	132.387
14	23.835	30	41.961
15	58.141	31	100.352
16	79.699	32	135.049

Table 38: Forecasts for the next years
Source: Own elaboration

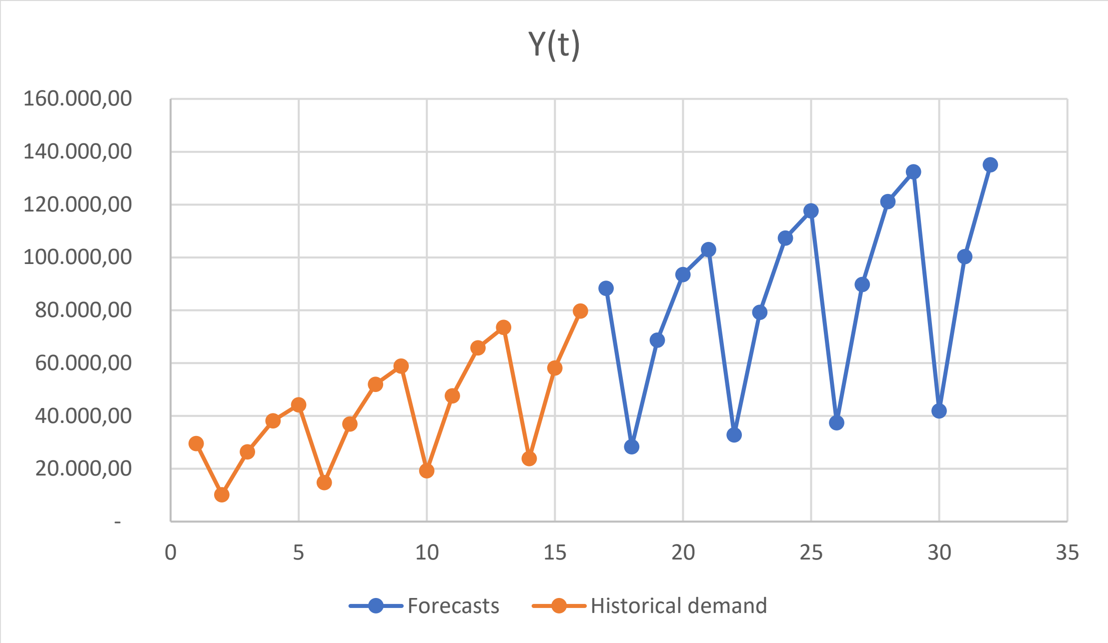


Figure 39: Forecasts for the next years
Source: Own elaboration

5.2. Capacity

The results of the production planning are shown below:

Month	Demand	K	c	cp	cs	sp
1	2208	864	750	150	30	745
2	1325	864	500	100	20	745
3	883	864	500	100	20	745
4	426	864	500	100	20	745
5	567	864	500	100	20	745
6	426	864	500	100	20	745
7	687	864	500	100	20	745
8	343	864	500	100	20	745
9	2404	864	500	100	20	745
10	1871	864	500	100	20	745
11	935	864	500	100	20	745
12	1871	864	500	100	20	745

Table 39: Parameters for the model
Source: Own elaboration

Month	Stock	Production	Additional capacity	Demand	Capacity
0	0	0	0	0	0
1	0	2208	1344	2208	2208
2	0	1325	461	1325	1325
3	0	883	19	883	883
4	0	426	0	426	864
5	0	567	0	567	864
6	0	426	0	426	864
7	0	687	0	687	864
8	500	843	0	343	864
9	0	1904	1040	2404	1904
10	0	1871	1007	1871	1871
11	0	935	71	935	935
12	0	1871	1007	1871	1871
TOTAL	500	13946	4949	13946	15317

Table 40: Variables (color blue)
Source: Own elaboration

Objective Function	6.064.270,00

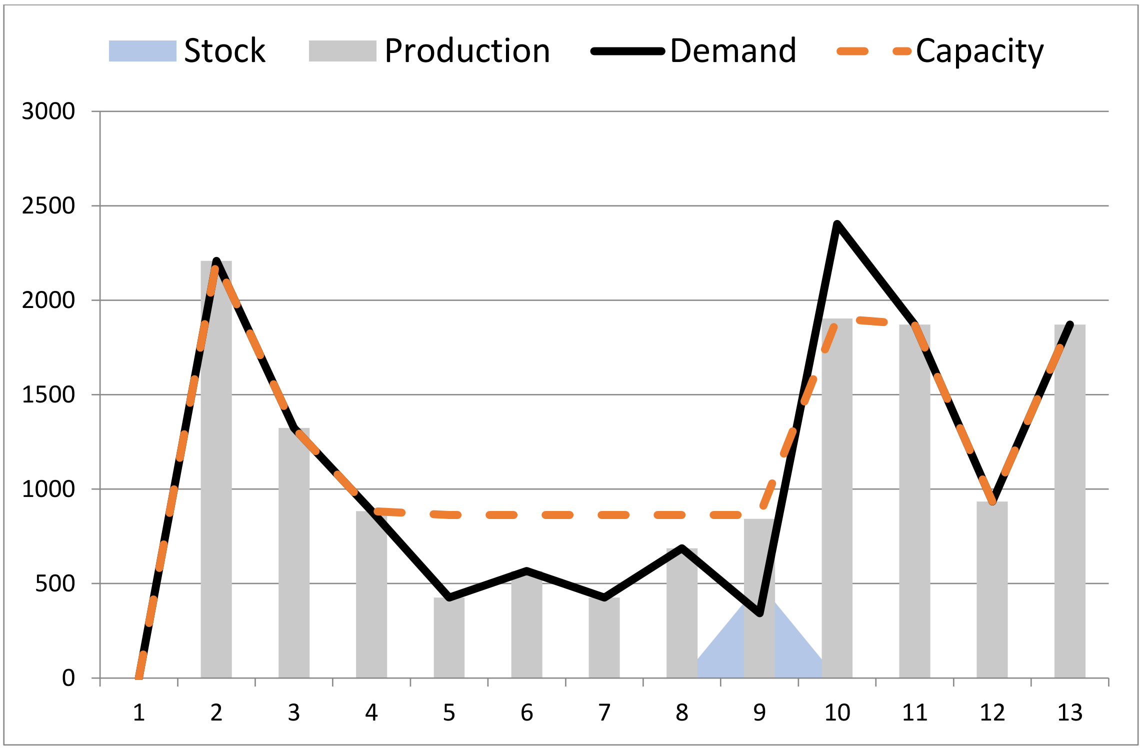


Figure 40: Production and capacity planning for the next year
Source: Own elaboration

5.3. Location

The following table shows the critical factors of the Brown & Gibson model. If a critical factor is found in a country, then it is 1. In the case of not being able to find any of these factors, then it would be 0. In Uruguay and Paraguay there is a 0 in the raw material factor because they do not have carbon fiber in the country.

Location	Energy	Water	Labor force	Raw material	CFi
Brazil	1	1	1	1	1
Argentina	1	1	1	1	1
Chile	1	1	1	1	1
Uruguay	1	1	1	0	0
Paraguay	1	1	1	0	0

Table 41: Critical factors
Source: Own elaboration

The next thing is to calculate the objective factors. In this case, rent and labor force have been chosen. The data shown in the table is in thousands of Brazilian reais (R $). The rent is approximately what you can find in those countries on the internet and labor force price is considered to be the minimum salary in the country multiplied by 10 workers.

Location	Rent	Labor force	Ci	1/Ci	OFi
Brazil	10	119,76	129,76	0,007706535	0,40611154
Argentina	13,7	136,8	150,5	0,006644518	0,3501464
Chile	14,6	201,6	216,2	0,004625347	0,24374206
			TOTAL	0,0189764	1

Table 42: Objective factors
Source: Own elaboration

To distribute the different weights to each subjective factor, you need to do this previous step. The factors are put in order. A 1 means that this factor is more important than the other. To be better understood, the factor (P) has a 1 in all the boxes because it is the most important of all and, therefore, the one that has the most weight.

	Factor j	P	T	I	C	S	CS	Sum	Wj
1	Proximidad clientes (P)	1	1	1	1	1	1	6	0,286
2	Comunicaciones (T)	0	1	1	1	1	1	5	0,238
3	Impuestos (I)	0	0	1	1	1	1	4	0,190
4	Competencia (C)	0	0	0	1	1	1	3	0,143
5	Seguridad (S)	0	0	0	0	1	1	2	0,095
6	Clima social (CS)	0	0	0	0	0	1	1	0,048
							TOTAL	21	1

Table 43: Weight for each subjective factor *j*
Source: Own elaboration

P	Brazil	Argentina	Chile	Sum	Ri1
Brazil	1	0	0	1	0,167
Argentina	1	1	1	3	0,500
Chile	1	0	1	2	0,333
TOTAL				6	1,000

T	Brazil	Argentina	Chile	Sum	Ri2
Brazil	1	0	0	1	0,167
Argentina	1	1	1	3	0,500
Chile	1	0	1	2	0,333
TOTAL				6	1,000

I	Brazil	Argentina	Chile	Sum	Ri3
Brazil	1	0	0	1	0,167
Argentina	1	1	0	2	0,333
Chile	1	1	1	3	0,500
TOTAL				6	1,000

C	Brazil	Argentina	Chile	Sum	Ri4
Brazil	1	1	1	3	0,500
Argentina	0	1	0	1	0,167
Chile	0	1	1	2	0,333
TOTAL				6	1,000

S	Brazil	Argentina	Chile	Sum	Ri5
Brazil	1	0	0	1	0,167
Argentina	1	1	0	2	0,333
Chile	1	1	1	3	0,500
TOTAL				6	1,000

CS	Brazil	Argentina	Chile	Sum	Ri6
Brazil	1	1	0	2	0,286
Argentina	1	1	0	2	0,286
Chile	1	1	1	3	0,429
TOTAL				7	1,000

Table 44: 6 tables, one for each subjective factor
Source: Own elaboration

With all those 6 tables (one per each factor) and the weights for each factor, it is time to calculate the subjective factors:

	R1j	R2j	R3j	Wj
Proximidad clientes (P)	0,167	0,500	0,333	0,2857
Comunicaciones (T)	0,167	0,500	0,333	0,2381
Impuestos (I)	0,167	0,333	0,500	0,1905
Competencia (C)	0,500	0,167	0,333	0,1429
Seguridad (S)	0,167	0,333	0,500	0,0952
Clima social (CS)	0,286	0,286	0,429	0,0476
SFi	0,220	0,395	0,385	

Table 45: Subjective factors
Source: Own elaboration

Finally, it is important to play with the alpha weights in order to see which country the best candidate is to create the factory:

	OFi	SFi	IL (alfa=0,3)	IL (alfa=0,4)	IL (alfa=0,5)	IL (alfa=0,6)	IL (alfa=0,7)
Brazil	0,406	0,220	0,276	0,294	0,313	0,332	0,350
Argentina	0,350	0,395	0,381	0,377	0,372	0,368	0,363
Chile	0,244	0,385	0,343	0,329	0,315	0,300	0,286

Table 46: Different results depending on alpha's value
Source: Own elaboration

The best location is Argentina and it doesn't depend on alpha's value. Also, we can see that there is not any country dominated as the example shown in chapter 4.

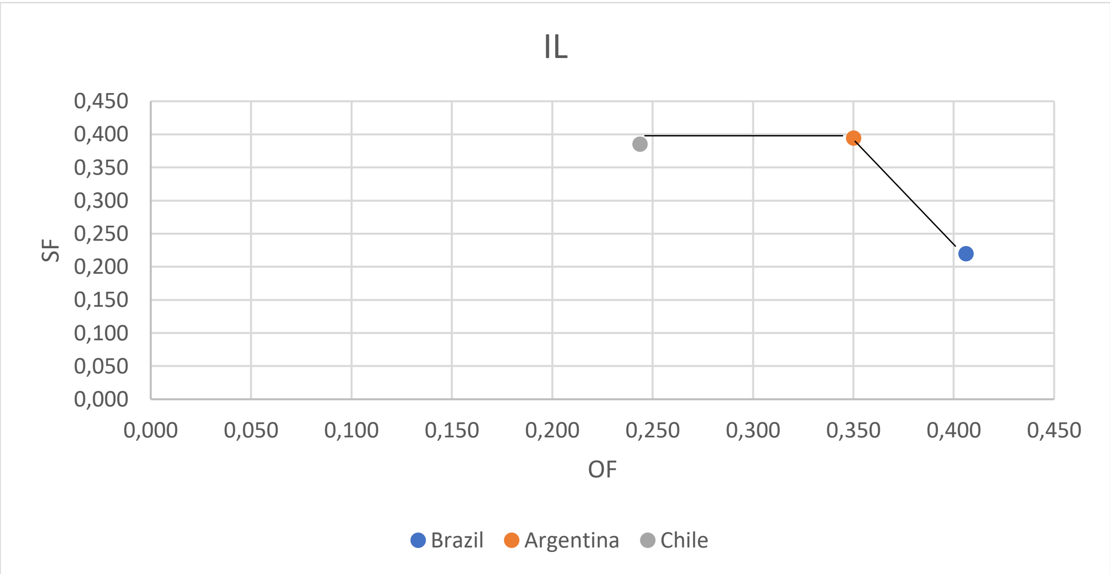


Figure 41: None of the countries is dominated by the others
Source: Own elaboration

5.4. Distribution

First, a warehouse must be created in Argentina according the results:

	Yi
Brazil	0
Argentina	1
Chile	0
Uruguay	0
Paraguay	0

Table 47: Results for *Yi*
Source: Own elaboration

Then, all the countries are served by the warehouse that was created in Argentina as we can see on the table below:

Xij	Brazil	Argentina	Chile	Uruguay	Paraguay
Brazil	0	0	0	0	0
Argentina	1	1	1	1	1
Chile	0	0	0	0	0
Uruguay	0	0	0	0	0
Paraguay	0	0	0	0	0

Table 48: Results for the matrix *Xij*
Source: Own elaboration

6. Environmental impact

Fiberglass and carbon fiber are not very sustainable. As has been said in the chapter on reverse logistics. The objective of this company is not to recycle (since it is impossible nowadays) but to reuse the sticks to produce less. Providing a good second-hand reconditioned stick can be better than a lower quality first-hand stick. Although there are studies that try to recicle carbon fiber, the most important thing is to focus on not wasting this material. Monitoring the manufacturing process avoids having to discard possible defective sticks. Thus, it is known that the material is harmful, but the intention is to reduce its consumption compared to other existing factories.

Conclusions

First of all, indicate that the results obtained make a lot of sense. It is normal for a country like Argentina to have as much superiority as the others (talking about field hockey). Attempts have been made to prove that the best strategy for the supply chain is not the most obvious, but in this case the most obvious option (Argentina) is the best one to locate both the factory and the warehouse.

Even so, it has been very interesting trying to create the supply chain in a region like South America. One of the main problems has been de date. It is really hard to fine good data to use, and many times there is nothing about what you are looking for. The scope of the project had to be bigger but due to lack of information it had to be reduce. It has also had to be changed some of the initial ideas because of this.

Bibliography

[1] McBryde, John. “About Field Hockey.” *FIELD HOCKEY BC*, 2019, www.fieldhockeybc.com/about/about-field-hockey/.

[2] Megan. “Field Hockey Stick Buyers Guide.” *SPORTS Unlimited*, Dec. 2014, www.sportsunlimitedinc.com/how-to-buy-a-field-hockey-stick.html

[3] “Stick Guide.” *OSAKA HOCKEY*, 2019, www.osakahockey.co.za/pages/stick-guide.

[4] “Where Is Sialkot, Pakistan?” *Wolrd Atlas*, 2019, www.worldatlas.com/as/pk/pb/where-is-sialkot.html.

[5] Decathlon Hockey. “How Hockey Sticks Are Made.” *YouTube*, 21 Aug. 2018, www.youtube.com/watch?v=CW6mr-YhYwA.

[6] Stage Pakistan. “Composite Hockey Manufacturing in Sialkot - Stage Pakistan.” *YouTube*, 3 Oct. 2017, www.youtube.com/watch?v=XVRz8D9rvgc.

[7] Irfan Saghir Mirza. “Sialkot Hockey Industry.” *YouTube*, 6 Jan. 2017, www.youtube.com/watch?v=puZyfgu43hY&t=86s.

[8] Muhammad Arfan. “How It’s Made - Model Composite Field Hockey Sticks.” *YouTube*, 28 Dec. 2013, www.youtube.com/watch?v=SfNG3Mk6JmE.

[9] “FIH RANKINGS.” *FIH*, June 2019, www.fih.ch/rankings/outdoor/.

[10] *Canário Hóquei*, 2019, https://www.canariohoquei.com/.

[11] *Balling Hockey*, 2019, https://www.ballinghockey.com/.

[12] *Flick Hockey*, 2019, https://www.flickhockey.com/.

[13] *Malik Hockey*, 2019, https://www.malik-hockey.com/.

[14] *Federación Panamericana de Hockey*, 2019, http://www.panamhockey.org/es/home.

[15] “Mapa América del Sur”, *D-maps*, 2019, https://d-maps.com/carte.php?num_car=2319&lang=es.

[16] ETSEIB, UPC. *Previsiones*. Departament d’Organització d’Empreses d’Enginyeria Industrial de Barcelona, 2019.

[17] *SABI*, 2019, https://sabi.bvdinfo.com/

[18] ETSEIB, UPC. *DCA. Planificación Estratégica de La Capacidad*. Departament d’Organització d’Empreses d’Enginyeria Industrial de Barcelona, 2019.

[19] ETSEIB, UPC. *DCA. Localización*. Departament d’Organització d’Empreses d’Enginyeria Industrial de Barcelona, 2019.

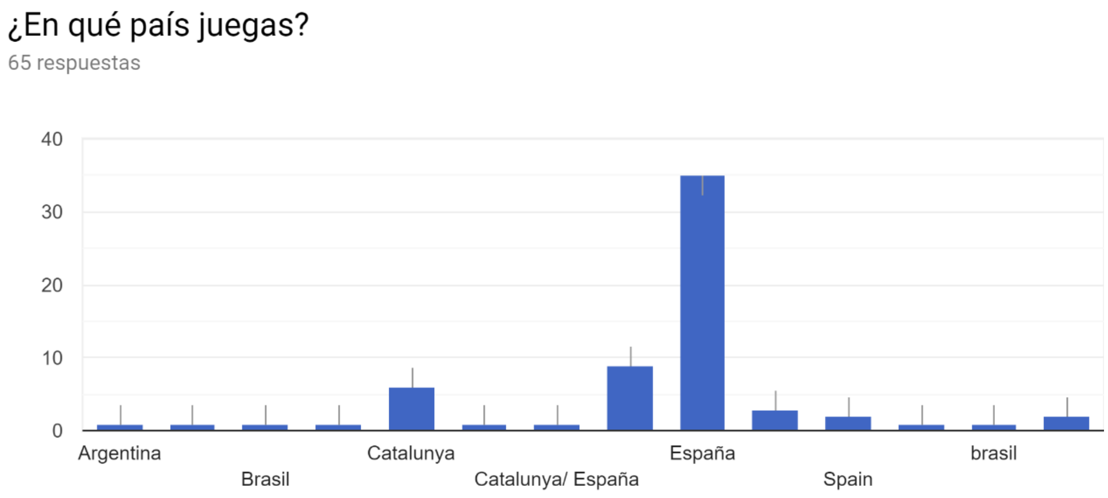
[20] ETSEIB, UPC. *DCA. Diseño de la red de Distribución*. Departament d’Organització d’Empreses d’Enginyeria Industrial de Barcelona, 2019.

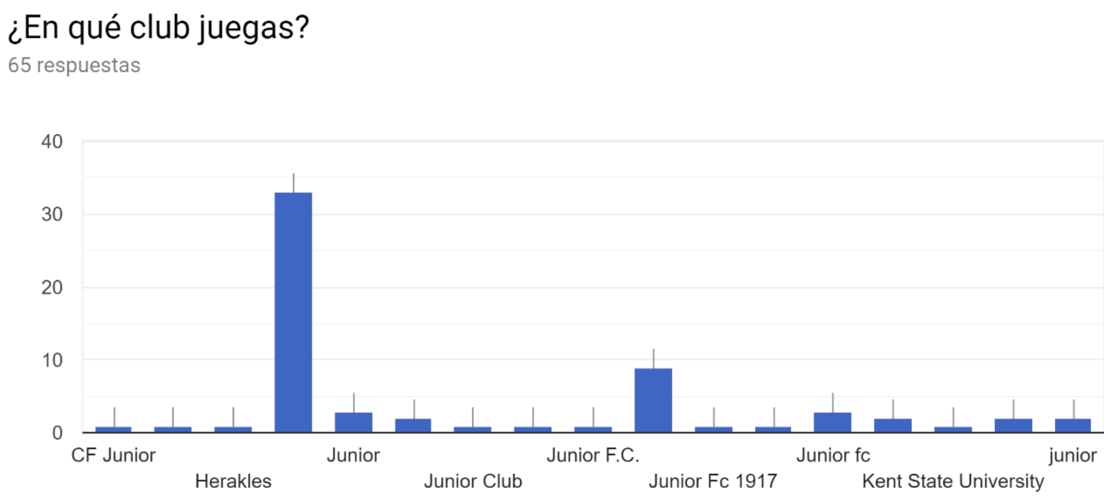
[21] *Google Maps*, 2019, https://www.google.com/maps/@-22.970898,-43.1844011,15z

[22] ETSEIB, UPC. *DCA. Logística Inversa*. Departament d’Organització d’Empreses d’Enginyeria Industrial de Barcelona, 2019.

Annex

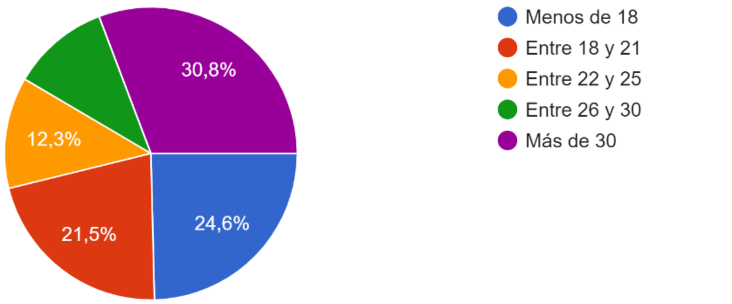
Annex A: Google Form about hockey





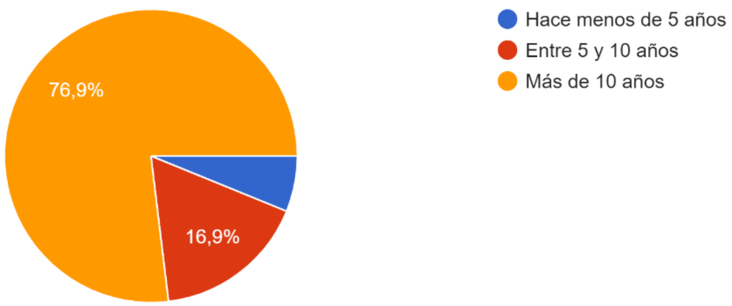
¿Cuántos años tienes?

65 respuestas



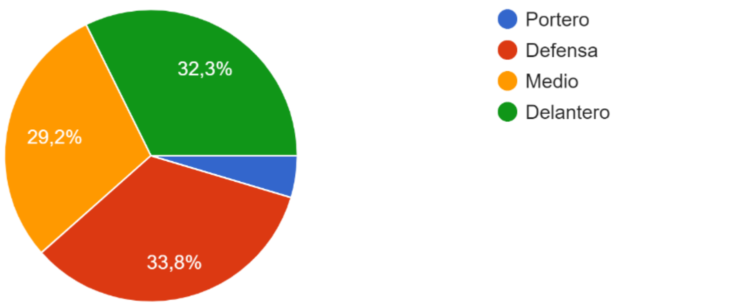
¿Cuánto tiempo hace que juegas?

65 respuestas



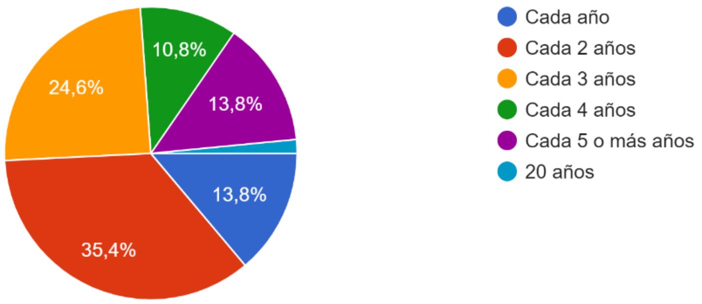
¿En qué posición juegas?

65 respuestas



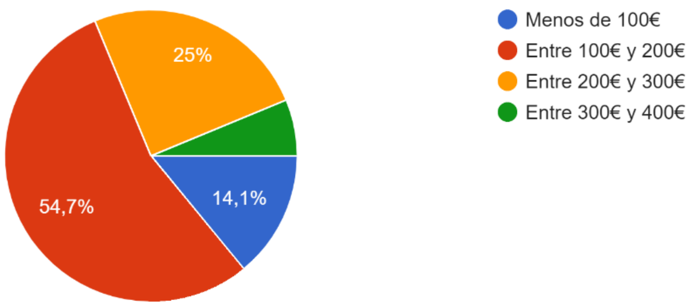
¿Cada cuánto tiempo compras o recibes un stick nuevo?

65 respuestas



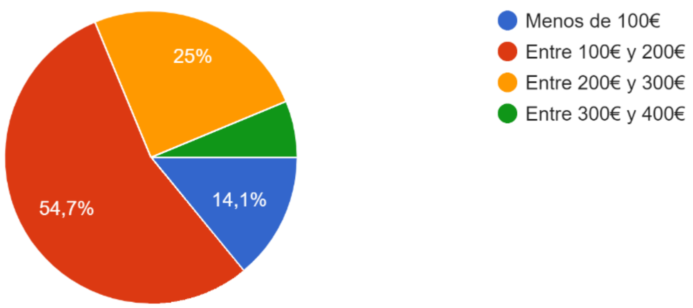
¿Cuál es el presupuesto de tu stick?

64 respuestas



¿Cuál es el presupuesto de tu stick?

64 respuestas



Annex B: IBM CPLEX Code

```
.MOD
int T=...;
int US=...;
int s0=...;
int D[1..T]=...;
int K[1..T]=...;
float c[1..T]=...;
float cp[1..T]=...;
float cs[1..T]=...;
float pv[1..T]=...;

dvar int+ x[1..T];
dvar int+ s[0..T] in 0..US;
dvar int+ ce[1..T];
dvar float B;

 maximize
      B;

      subject to
      {
            B==sum(t in 1..T)(pv[t]*D[t]-cp[t]*x[t]-cs[t]*s[t]-
c[t]*ce[t]);

            s[0]==s0;

            forall(t in 1..T)
              {
                  s[t-1]+x[t]==D[t]+s[t];
                  x[t]<=K[t]+ce[t];

              }
      }


.DAT
SheetConnection excel("P3 v3.xlsx");

T from SheetRead(excel,"Dades!B1");
US from SheetRead(excel,"Dades!B2");
s0 from SheetRead(excel,"Dades!B3");
D from SheetRead(excel,"Dades!B10:B21");
K from SheetRead(excel,"Dades!C10:C21");
c from SheetRead(excel,"Dades!D10:D21");
cp from SheetRead(excel,"Dades!E10:E21");
cs from SheetRead(excel,"Dades!F10:F21");
pv from SheetRead(excel,"Dades!G10:G21");


s to SheetWrite(excel,"Resultats!B2:B14");
x to SheetWrite(excel,"Resultats!C3:C14");
ce to SheetWrite(excel,"Resultats!D3:D14");
B to SheetWrite(excel,"Resultats!J1");
```

Annex C: Forecast Excel (Multiplicative model)

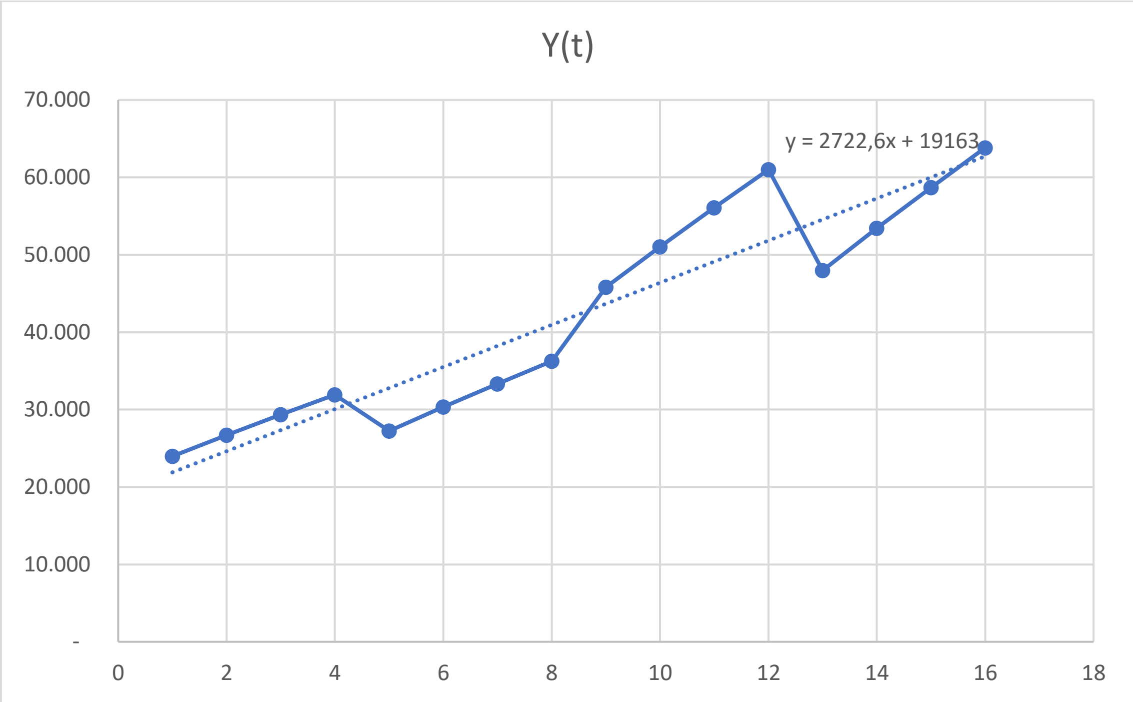
Año	Trimestre (t)	x(t)	M1	M2	f'(t)	C(t)=x(t)/f'(t)	c1(t)	Y(t)=x(t)/c1(t)	f2(t)	C(t)=x(t)/f2(t)	c2(t)	error entre c1(t) y c2(t)	Y'(t)
2015	1	33.560			17385,6	1,93	1	23.969	21885,6	1,53	1	3,90%	29.529
2015	2	11.187			20675	0,54	0	26.699	24608,2	0,45	0	0,82%	10.240
2015	3	27.967			23964,4	1,17	1	29.333	27330,8	1,02	1	1,48%	26.483
2015	4	39.154	27.967		27253,8	1,44	1	31.900	30053,4	1,30	1	3,28%	38.186
2016	5	38.125	29.108		30543,2	1,25	1	27.229	32776	1,16	1	3,90%	44.223
2016	6	12.708	29.488		33832,6	0,38	0	30.330	35498,6	0,36	0	0,82%	14.772
2016	7	31.771	30.439	29.251	37122	0,86	1	33.322	38221,2	0,83	1	1,48%	37.036
2016	8	44.479	31.771	30.202	40411,4	1,10	1	36.238	40943,8	1,09	1	3,28%	52.024
2017	9	64.167	38.281	32.495	43700,8	1,47	1	45.828	43666,4	1,47	1	3,90%	58.917
2017	10	21.389	40.451	35.236	46990,2	0,46	0	51.048	46389	0,46	0	0,82%	19.303
2017	11	53.473	45.877	39.095	50279,6	1,06	1	56.084	49111,6	1,09	1	1,48%	47.589
2017	12	74.862	53.473	44.521	53569	1,40	1	60.992	51834,2	1,44	1	3,28%	65.862
2018	13	67.155	54.220	48.505	56858,4	1,18	1	47.963	54556,8	1,23	1	3,90%	73.611
2018	14	22.385	54.469	52.009	60147,8	0,37	0	53.425	57279,4	0,39	0	0,82%	23.835
2018	15	55.963	55.091	54.313	63437,2	0,88	1	58.696	60002	0,93	1	1,48%	58.142
2018	16	78.348	55.963	54.936	66726,6	1,17	1	63.832	62724,6	1,25	1	3,28%	79.699

a	4228
b	3289,4
a'	14096,2

	c1(t) promed	ajustado	c2(t) promed	ajustado
1r trimestre	1,46	1,40	1,349	1,348
2º trimestre	0,44	0,42	0,416	0,416
3r trimestre	0,99	0,95	0,969	0,968
4º trimestre	1,28	1,23	1,271	1,269
	4,16	4,00	4,005	4,000

a	19163
b	2722,6

Correcció final	
a'	19.186,939
b'	2.726,001


Y(t)
y = 2722,6x + 19163
70.000
60.000
50.000
40.000
30.000
20.000
10.000
-
0
2
4
6
8
10
12
14
16
18